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Edited by

ROLAND V. NORRIS, D. Sc., F.R.I.C.
Director, Tea Research Institute.

THE TEA RESEARCH INSTITUTE
St. Coombs, Talawakelle.

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The Tea Research Institute of Ceylon.

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Superintendent, St. Coombs Estate ... F. C. Daniel

NOTE

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JOHN A. ROGERS

John Rogers, Superintendent of St. Coombs Estate, from 1928-1946, died at the Hatton Nursing Home on the 7th September after a long and trying illness borne with characteristic patience and courage.

Rogers was born at Burnnam-On-Crouch in 1885. On leaving Uppingham he at first contemplated taking up architecture as a career, and served an apprenticeship in that profession. His preference for an open air life induced him, however, to leave England in 1907 for British Columbia where he remained until 1914.

On the outbreak of the First World War he returned home and enlisted in the 12th (Bermondsey) Bt. East Surrey Regiment. His efficiency was quickly recognised by the grant of a commission and he served with much distinction in France and Italy, being awarded the Military Crcss and two Bars. A fellow officer of the Battalion refers to him as "The most liked Company Commander the Battalion ever had —— His quiet cheeriness even under appalling circumstances kept us fighting long after we could presumably have cleared out."

On demobilisation Rogers decided to take up planting and he came out to Ceylon in 1920 as an Assistant on Poonagalla Group where he remained until December. 1928, when he was appointed Superintendent of St. Coombs. The Estate had only recently been acquired by the Institute and Rogers had the responsible task of organising the estate side of the Institute's activities. The thoroughness with which he carried out this work has left a permanent mark on St. Coombs.

In 1945, while on leave in Australia, Rogers had a breakdown in health which to the lasting regret of all his colleagues led to his retirement in 1946 after nearly eighteen years service with the Institute.

Rogers disliked publicity of any kind but St. Coombs remains as a tribute to his efforts and the kind of tribute which he would most have appreciated. A man of the highest personal integrity, thoroughness was his outstanding characteristic. St. Coombs Estate was the absorbing interest of his planting life and he devoted all his energies and strength, even when the latter began to fail, to the efficient conduct of his work. By nature of a somewhat conservative turn of mind, he must sometimes have regarded his scientific colleagues as a trial, and viewed their technical approach to estate problems with some misgiving. The writer, however recalls with affectionate gratitude his complete loyalty and co-operation and, particularly, the invaluable help he gave in creating the St. Coombs which exists today.

"J.A." with his somewhat shy and gentle reserve was perhaps not easy to get to know His friendship when gained was, however, staunch and firm and will remain a pleasing memory to his colleagues as also will the recollection of occasions when in congenial company he would unbend and with a puckish spirit all his own, add zest and amusement to a festive evening.

R. V. N

REPORT OF ADDRESSES GIVEN BY DR. R. V. NORRIS AND MR. J. LAMB AT THE MEETING OF THE STANDING COMMITTEE FOR AGENCY AFFAIRS HELD ON THE 12TH OCTOBER, 1949.

BLISTER BLIGHT.

DR. NORRIS: I am glad to take this opportunity of advising you as to the steps which have been taken to implement the decisions reached at recent meetings of the General Committee of the Planters' Association of Ceylon and of your Section in regard to advice and assistance in the Control of Blister Blight.

You will remember no doubt, but I particularly wish to stress this point, that I explained at these meetings that work on Blister Blight should be considered from two main aspects — (1) the laboratory side consisting in the main in the study of the causative fungus and (2) the field aspect of preventative measures, dealing with improved spraying technique and testing of spraying equipment and fungicides of different types.

As regards (1) I think there is a good deal of misunderstanding as to what has already been done by the Institute. The work carried out by the Tea Research Institute staff, and in particular by Dr. Gadd and Mr. Loos, has already elucidated the life history of the fungus, the way in which it attacks the tea bush and the general conditions under which attacks become intensified or reduced.

It may be said with confidence that this side of the work has reached a stage when our laboratory knowledge no longer constitutes any limiting factor on practical protective work in the field. An account of some of this work will be found in this issue of the Tea Quarterly. On the field side the main problem is how to meet the difficulties due to local conditions of climate and terrain, and, in short, to obtain or devise spraying equipment which may render spraying an economic proposition. With this is of course combined the testing of different types of fungicides, and in this connection the Institute has been in touch with producers in many different countries and has already received numerous new products for test.

It is in connection with the field work outlined above that it was considered time could be saved and valuable assistance obtained by securing the services of experts experienced in plant protection work. You will remember that it was decided that as the first step an officer or officers should be asked to come out to Ceylon in the immediate future to make a preliminary survey of the whole position. On the basis of their examination and the advice they will tender it will be possible to draw up a programme of future work and to decide what additional staff, if any, may be required.

This policy has been implemented and the Institute has been able to make arrangements on very favourable terms for two experts, one from Plant Protection Ltd. and one from Pest Control Ltd. to come out immediately to make this preliminary sur-

vey. Mr. Lane of Plant Protection Ltd., will be arriving in Colombo on the 16th October, and Dr. Greenslade, who is on the staff of Pest Control Ltd., ten days later. Mr. Lane has wide experience of spraying technique and has recently been in charge of operations against the Colorado Beetle in the United Kingdom, while Dr. Greenslade is the Chief Biologist of Pest Control Ltd. The investigations of these two officers will, therefore, be complementary to each other.

Preliminary plans have already been drawn up so that there may be no delay before these officers commence work. Three different types of modern spraying equipment have already been obtained for test, two of which have reached Ceylon, while the third will arrive before the end of the month. A considerable number of hitherto untried fungicides, including organics free of heavy metals, have also been obtained.

The two officers will be accommodated at St. Coombs but will, of course, have full opportunities to study Blister Blight in different areas where different conditions obtain.

The necessary subordinate staff has been provided and a spraying gang is under training.

The Institute has agreed to be responsible for the cost of this preliminary work though it is hoped it will be possible to reimburse us from other funds. In this connection it is understood that the Minister of Agriculture is prepared to increase the Tea Control Cess from 5 to 10 cents and to set free the funds thus accumulated for work against Blister Blight. This increase in cess should produce about Rs. 150,000 per annum.

I hope the Committee will feel satisfied, therefore, that all necessary steps have been taken to implement the decisions previously reached. In this connection I am greatly indebted to Mr. Lamb, the Deputy Director of the Institute, who, in a very hurried visit to England, interviewed both Plant Protection Ltd. and Pest Control Ltd. as well as other authorities and completed arrangements which otherwise would have taken a good deal longer to make.

I now wish to refer very briefly to a letter recently sent to the Agency Section by one of the Colombo Agency Houses in which they mention that one of the Companies with which they were associated had suggested that the work of the Institute should for all practical purposes be concentrated entirely on Blister Blight, other lines of investigation being suspended.

Such a suggestion seems to me to be based on a complete misunderstanding of the position, and after what I have said this morning I hope you will agree with this view and concur that such a panic measure would be quite unjustified and in the highest degree detrimental to the interests of the Tea Industry. I feel sure I am speaking for the Board of the Institute when I suggest that they would not consider such a proposal.

What I have said gives a very brief view of the position, and I shall of course be only too glad to answer any questions you may wish to put to me. I think also you would like to listen to Mr. Lamb for a few moments; he will be able to tell you something of his discussions in England from which the present arrangements have resulted.

I shall myself be going on leave out of Ceylon next month and for this reason Mr. Lamb, who will be acting for me as Director, has already been placed in immediate administrative charge of the Blister Blight survey.

It is proposed while this survey is taking place to arrange for a technical discussion at St. Coombs on all aspects of Blister Blight. Invitations have been sent to Java, N. E. Indies and S. India to send technical officers to take part in this conference, and there is every reason to believe that these invitations will be accepted. It will then be possible to collate all information available in regard to Blister Blight and I cannot doubt but that the pooling of experience will be most helpful.

I mentioned earlier that we had recently obtained new spraying equipment and it may, therefore, be of interest to you if I give you some figures in regard to a preliminary trial carried out with one of these — a Four Oaks Central Charging Battery Spraying Set. These are as follows :—

Area.—A six-acre block of *pruned tea* of extremely steep and difficult land in the Dimbula District.

Labour.—Eight men, one at the charging station and one on each of the seven sprayers.

Time.—Work commenced at 8-45 a.m. and finished at 1 p.m., i.e., 4¼ hours to cover six acres. There was some delay owing to technical hitches with the new plant, and this time could probably be reduced by at least 30 minutes.

Material Used.—52 gallons spraying liquid = 8½ gallons per acre. Spray used — Perenox at the rate of 4 ozs. in 10 gallons.

Approximate Cost :—

Labour	...	Rs. 12.48
Perenox	...	„ 2.15
		Rs. 14.63

= Rs. 2.44 per acre.

As mentioned, a new untried machine was being used and the gang in charge were only partially trained. It is estimated that with further experience, the cost of spraying under these conditions, i.e., in pruned tea, might be reduced to Rs. 2 per acre.

An estate gang was working on another area with ordinary individual-charge sprayers. The cost in these circumstances amounted to about Rs. 6 per acre.

Apart from pruned areas, one of the chief problems to be considered is the probable cost of spraying with tea in plucking. This will naturally vary considerably on different estates according to local conditions and the liability to Blister Blight attacks.

Mr. Lamb : Dr. Norris has dealt with the administrative aspects of our work on Blister Blight and I will now give you more technical details of our progress. I use the word progress deliberately because we have progressed, and I think it probable that the work done at the T. R. I. is not fully appreciated. A few months ago there certainly was, and possibly there still is, a feeling that we are not doing enough. There was talk of bringing out teams of experts to tackle the problem and, I suspect, a feeling that if only the services of "Headline" men could be obtained progress would be greatly accelerated.

As Dr. Eden expressed the position in a recent address to the Ceylon Association in London, you must not place any faith in the idea that a team of atomic scientists can come out to Ceylon and settle the whole matter in five minutes. In fact, even the Experts in England have their own troubles. Let me quote from proceedings at Westminster :—

"*Plant Disease (Fertilisers).*—On May 12, Mr. Collins asked the Minister of Agriculture if he will

appoint a committee to enquire into the causes of increase in plant disease, the possible connection with the greater use of artificial fertilisers, and the comparative results achieved by the Indore and similar methods depending on the biological basis of soil fertility.

The Minister of Agriculture (Mr. T. Williams). No. Sir, I am advised that there is no evidence that the increasing use of so-called artificial manures has had the effect that is suggested. I would add that scientific opinion is unanimous that the so-called artificial fertilisers should be supplemented by the addition to the soil of organic materials such as dung and compost or by the ploughing-in of grass and clover swards."

This is very reminiscent of a controversy that raged in Ceylon ten years ago. I am not suggesting that we consider ourselves to be ten years ahead of Agricultural Science in England but it serves to make a point that even the experts in that country are accused of complacency and inaction in the odd moments when they are not being accused of progressing too fast for the humanities.

The same view was expressed by Sir John Russell, this year's President of the British Association of Science :—

"More intense cropping also calls for strict measures against pests and diseases which now *travel* (of Blister Blight from N. India) widely and are favoured by the greater crowding of crops. Resistance is fairly frequently a heritable character, and once the genes are found, resistant varieties can be produced, such as the potatoes bred at Cambridge and at Corstorphine. Measures for protecting plant and animal health are being steadily improved ; if in spite of all precautions the attack still comes, counter-measures can often be taken. Plant virus diseases still defeat us, but the able and persistent efforts of the various workers in this field cannot fail to bear fruit."

I think that every Scientific Worker associated with the tea industry has at some time referred to the extraordinary freedom from disease that tea in general has enjoyed, especially as it is grown under a system of continuous cropping which is the worst possible condition for encouraging fungus and insect attack.

As soon as Blister Blight arrived Dr. Gadd quickly explained that it is not a *virus* disease (cf. Sir John Russell's remark) and that, unlike the Coffee disease, it does not attack mature foliage leaf and is not therefore necessarily fatal.

Viewed from the standpoint of plant diseases in general, it could be very much worse. I can assure you from personal experience that this is so because, during my student days, I received a travelling grant from the United Fruit Company which took me through Costa Rica during the height of the Panama disease of Bananas epidemic. The miles after miles of ravaged plantations and utter desolation was a sight I shall never forget.

Now, I do not want to underestimate the importance of our problem, but to point out that neither Experts, Divine Inspiration or Panic offer any immediate end to our troubles. Systematic and painstaking work may, and I am tempted to say will, bring some reward in time.

Counter measures to plant or any disease develop in three stages :—

Firstly.—The investigation of the exact nature and course of the disease.

Secondly.—Reconnaissance of all possible protective measures.

Thirdly.—The trial of selected protective measures with adequate provision for testing efficiency and cost.

In the case of Blister Blight, the first stage has been completed by the painstaking and systematic work of Dr. Gadd and Mr. Loos. I assure you that no Mycologist could have completed this task more efficiently or quickly than Dr. Gadd with Mr. Loos's assistance. In any case, speed is governed by seasons and climatic conditions rather than speed of laboratory manipulations, for the disease had to be observed under all climatic conditions. Although North Indian experience provided some assistance, Dr. Gadd has carried his study a great deal further and his findings are much more conclusive. They are now permanently recorded in scientific literature and are accepted as work of the highest standard.

We therefore pass on to the second stage, namely, the reconnaissance of protective measures based on exact knowledge of the susceptible stages of the organism we are fighting. Considerable progress has already been made. We have no less than 20 proprietary funcicides in transit or under test. Two types of modern spraying equipment are on the way out and one is already in use. Field experiments with control measures occupy the entire time of the Mycology Department, a good deal of Mr. Portsmouth's and some of my own.

Now we fully realise that our experience in these matters is limited. Scientific training quickens the sense of one's limitations and we are only too glad to accept any offers of help from experts with wide experience of large scale Plant Protection work. It is a short cut which was not possible in Stage I because there just were not any Mycologists with the actual experience and knowledge of the Blister Blight fungus anywhere in the world.

We have to acknowledge our debt to Mr. G. K. Newton for opening up these possibilities which have resulted in the arrangements with Plant Protection Limited and Pest Control Limited.

For a number of reasons, it was necessary that I should go to the United Kingdom and it was possible to complete negotiations for assistance in this stage of Blister Blight work within a few weeks of the preliminary discussions in Colombo. Perhaps I should explain that, at the time I left Colombo, there was no certainty of any funds, beyond the normal resources of the T. R I., being available for Blister Blight work. It was essential to bear in mind that control measures must be strictly economic, so I confined negotiations to the two large organisations concerned with fungicides and their application. The fact that they are prepared to send out experienced men and to submit their recommendations to field trials, is a measure of their confidence in their organisation.

Messrs. Plant Protection Limited are a subsidiary of Imperial Chemical Industries, and their main concern is with fungicides and insecticides. They are sending out Mr. F. W. J. Lane, who has wide experience of large scale plant protection work, particularly the control of Colorado Beetle.

To some extent Messrs. Pest Control Ltd. are complementary to Plant Protection Limited, as their main concern is with spraying and dusting machinery, and with contract spraying and dusting services which they have recently extended from the United Kingdom to the Sudan. Their Biologist, Dr. Greenslade, has recently been concerned

as a co-author in the development of systemic insecticides which has been the centre of a great deal of scientific interest. Systemic insecticides have great practical possibilities and it is, of course, hoped that systemic fungicides will follow. The main feature of systemic insecticides is that they are absorbed by the plant and, for a period, render the tissues toxic to particular insects.

In both cases the first question I was asked was about Stage 1. I was able to give a clear, concise and complete information as a result of Dr Gadd's and Mr. Loos's work and I had the feeling that co-operation was obtained on the strength of this work.

Perhaps it will be as well if I now give you a summary of what has been established.

1. The disease is transmitted by spores. These spores are destroyed by a few minutes exposure to direct sunlight but can live for a week on an atmosphere at 90% relative humidity.

2. The spores alight mainly on the upper surface of leaves. Infection of undersurfaces is relatively small, which simplifies spraying problems.

3. Under special conditions of humidity and free moisture, e.g., Dew, the spores germinate in 6-24 hours.

On germination a mucilage is exuded which anchors the spore to the leaf and enables it to force a germ tube through the cuticle into the leaf tissue.

4. The germ tube is only able to penetrate leaves or stems up to 30 days old. Very occasionally it gains entry to an older leaf.

5. After the entry of the germ tube the fungus grows rapidly and causes translucent, i.e., semi-transparent, spots to appear in the leaf in 6-10 days. The fungus flowers and seeds, i.e., sporulates, in 18-21 days. The blister may therefore appear on leaves which are 30 + 18 days old and give the false impression that old leaves are being attacked. The spores are ejected with considerable force and are wind-borne.

Systemic fungicides may be found which are effective at this stage. The selection of resistant strains of tea must also be mentioned as a major method of control.

6. There is NO RESTING STAGE OF THE SPORE which enables it to survive for long periods under adverse conditions. There is NO ALTERNATIVE HOST (at present) which will harbour the disease.

Drought and sunshine therefore give a large measure of control, and after a long drought it takes a considerable time for the level of infection to build up.

The disease carries over through drought periods on new growth inside bushes where a "MICRO-CLIMATE" affords conditions favourable to the survival of the disease.

The fungus is highly susceptible to copper based fungicides, and it is hoped the work now in progress will reveal other products free from some of the disadvantages inherent in the use of heavy metals.

THE FUNGUS *EXOBASIDIUM VEXANS.*

C. H. GADD & C. A. LOOS

Since its arrival in Ceylon much has been written and said about the Blister Blight leaf disease of tea, but relatively little about the fungus *Exobasidium vexans* that causes it. As the rational treatment of any disease depends upon the knowledge of the causative organism an account of the fungus *E. vexans* may be of interest. At the same time we shall try to indicate how that information bears on rational treatment.

The fungus was described and named *Exobasidium vexans* by Massee in 1898 from material sent to him from Assam by Dr. Watt where it was causing serious damage to tea. The disease (blister blight) was described in North India by Watt and Mann (1903), McRae (1910) and Tunstall and Bose (1921); in Indo-China by Du Pasquier (1933); and in Formosa and Japan by Sawada (1922). It appeared for the first time in South India and Ceylon in 1946.

The disease first becomes evident on young expanding leaves as translucent spots which later become conspicuous circular 'blisters.' Normally the upper surface of the leaf becomes indented to form a circular pit and the lower surface protrudes to form the so-called blister (Plate 1, Fig. 1). Some days later the convex surface of the blister on the under surface of the leaf, becomes white and velvety as the fungus is revealed by the splitting and removal of the leaf's outer skin (the cuticle). Sometimes the convex surface of the blister is on the upper surface of the leaf ; but the fungus still appears on the under surface in the concave area. Occasionally the fungus is seen on both sides of the leaf but the bulk of it is usually on the lower side. Young growing stems are also affected but they are never 'blistered' and the fungus appears on their surfaces as white velvety patches which makes the stems appear thicker (Plate 1, Fig. 2). Young stems are frequently bent and distorted. Later, the white areas turn black and dry as both fungus and plant tissues die and the dead tissues may fall out leaving a hole. Buds are also destroyed. The green outer case of the fruit is sometimes infected but the fungus has not been found on seeds.

Most fungus parasites can be grown on media other than living tissues and so can be studied apart from their hosts ; but *E. vexans* is one which will not develop fully on any known medium other than the living tea plant. The main body of the fungus is within the infected leaf or stem and lives there so long as the invaded tissues remain alive.

The living fungus is visible to the unaided eye when it is producing spores. The outer surface of the leaf has then disintegrated and the fungus can be seen as a white sheet. Spores are formed in very large numbers over the whole of this surface which is termed the *hymenium*. The velvety appearance of the hymenium is due largely to the fungus threads being rounded at the ends and standing erect in compact bundles, which are parallel and close together like the pile of a carpet (Plate 2, Fig. 14). Amongst this 'pile' are slightly longer cells (basidia) which project above the general level. They also differ from the surrounding cells in that at their apices are two, three or four minute spikes *(sterigmata)* on each of which stands a spore

Plate 1. Blister blight on tea. (Upper) Blistered leaf. (Lower) Infected stem.

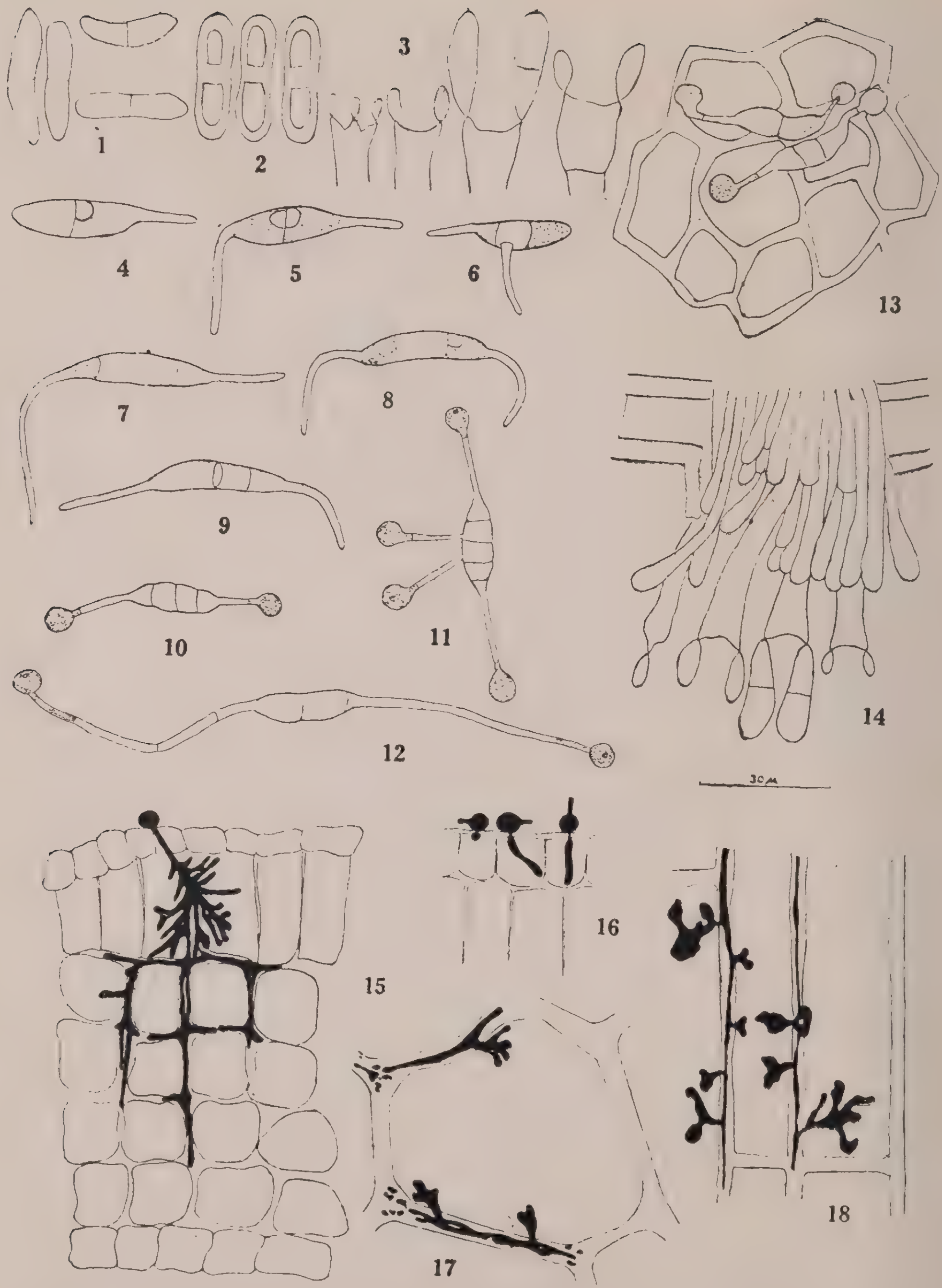

Plate 2. *Exobasidium vexans.* 1, Basidiospores. 2, Thick walled spores (abnormal). 3, Spore development on basidia. 4-9, germinating spores before the formation of appressoria. 10-12, Germinating spores with appressoria. 13, Germinating spores on leaf surface 14, Hymenium, showing basidia and spores. 15, Section through leaf showing the fungus shortly after entry. 16. The fungus immediately after entry. 17-18, Showing the fungus mycelium between cells and haustoria within the cells.

unless it has already been discharged (Plate 2, Fig. 3). After discharging all its spores the basidium collapses. These details can be determined only with a microscope and specially prepared specimens, and even then, the ripe or nearly ripe spores are usually dislodged during the preparation. In such preparations there appear to be spores of two kinds, smaller ones attached to basidia and larger ones usually consisting of two cells, lying on the surface of the pile. It is now known (Gadd and Loos 1948) that these are but different stages in the development of the one spore. The larger ones are fully mature spores; the smaller ones are not fully grown and are more firmly attached to the sterigmata.

The fully grown spores (Plate 2, Fig. 1) are of microscopic size and about 10,000 can lie side by side without overlapping on an area one millimetre square. So long as an infected leaf remains attached to the bush and the fungus is alive there is a continuous discharge of spores from the hymenial surface; but if the leaf is plucked, discharge soon ceases unless the leaf is supplied with water. The spores can be collected by cutting a fresh blistered leaf in the evening and arranging it with its cut end in water and the blistered surface just above, but not touching, a piece of glass, so that the spores will fall on to it. The whole is then covered with a large jar or other vessel so that the air currents do not carry the spores away. The next morning a white film of spores will usually be found on the surface of the glass. A very rough estimate of their number can be calculated from measurements of the area covered; the number will probably exceed a million. Other similar collections can be obtained from the same blister. No estimate of the total number of spores formed by one blister has been made, but an experiment of this sort shows it to be gigantic.

On a few occasions thick walled spores have been observed (Plate 2, Fig. 2). These are undoubtedly a later development of the thin walled spore. As yet they have not been seen to germinate. They have been found on old dried blisters and it seems doubtful that they serve any special function.

A piece of glass bearing a deposit of spores may be placed in running water, as from a tap, without dislodging the spores. They stick equally well to other surfaces such as cellophane, plastics and leaves. This adhesive property of the spores is probably of considerable importance to the fungus as it prevents their removal from leaves by heavy rain; it holds them in position till conditions are favourable for germination. Many find lodgment on unsuitable bodies and only a minute percentage of the spores formed can ever reach tissues in which they can develop. Gigantic numbers are necessary to ensure the survival of the species.

The spores are so light that they fall slowly in absolutely still air and any small air current will carry them away. The following experiment demonstrates how small, imperceptible air currents can carry the spores appreciable distances. An infected seedling was placed with the diseased leaf held vertical at one end of a large glass sided box which could be tightly closed. Pieces of glass were arranged on the floor and in different parts of the box before it was closed. The next day spores were found on all the glasses even those on the floor 30 inches away from the leaf. Similar results were obtained when the diseased leaf was held horizontally with the hymenium downwards. As the small air currents in the box can carry away the spores it is easy to imagine what occurs in the open air. Upward currents will carry the spores to great heights and horizontal currents will convey them great distances.

How the spores reached Ceylon is largely a matter of speculation. From the

evidence available it seems highly probable that they arrived by wind from South India, where the disease occurred a few months earlier than in Ceylon. They later travelled from the Western to the Eastern side in the same way. An alternative hypothesis is that they came attached to merchandise, clothing or other vehicle, but it has a serious objection. The spores would adhere firmly to such vehicles; but how would they become detached and then attached to a tea bush? Wind would carry a large number of spores, but only a very small percentage of those dropping on tea areas would lodge on tissues favourable for further growth. Infections would be likely to occur at widely separated places almost simultaneously. That is in fact what was observed. Within three weeks of the disease being first reported it was found on five widely separated estates in different planting districts. The importance of the three week period will become evident later.

Mention has been made of the sticky nature of the spores and the suggestion made that it prevented their removal from leaves by rain. It would, however, also prevent the spores from falling free into the air from the surface on which they are formed unless that surface were on the underside of horizontal leaves. Although the spores are formed on the lower surfaces of leaves, many diseased leaves and most diseased stems do not stand horizontally and so the chances of spores falling on and adhering to the leaf or stem on which they are formed are considerable. This risk is diminished very considerably by the spores being forcibly discharged into the air. The distance they are shot into the air is very small, only a small part of a millimetre, yet it is sufficient to free the spores from the surface and give them a clear start. As we have already seen even small convection currents are sufficient to carry them away. What happens later is purely a matter of chance. Some may be carried long distances and others will find lodgment nearby. Only a very small percentage will fall on young tea leaves and stems. How large a number is represented by that very small percentage is evident in the fields.

The spores do not begin to grow until they are wetted, and they germinate best in a minimum of water. A thin film of water is more favourable for germination than is a spot, and ideal conditions are obtained when water vapour condenses as dew around the spore. This is probably one of the reasons why the disease is often most prevalent in areas liable to mist, and in hollows where dew forms early.

The first indication that a spore has begun to germinate is the emergence of a thin tube from one or both ends of the spore (Plate 2, Figs. 4-9). This many occur very soon after the spore is wetted. On occasions, these germ tubes have been observed in the laboratory in one and half hours after wetting. Sometimes, a third and even fourth germ tube may emerge from one spore; these come from the side walls. The contents of the spore flow into the germ tubes leaving the spore case empty. The normal number of germ tubes is two, one from each end, and the empty spore then has one wall dividing it into two compartments. When three germ tubes arise the empty cell has two dividing walls making three compartments. The number of germ tubes arising from a spore depends upon the number of dividing walls within it, as each compartment may give rise to a germ tube.

The germ tubes normally continue to elongate until they are equal to three or four spore lengths when each tube begins to enlarge at the tip to form a ball-like termination. These spherical bodies at the end of the germ tubes are termed *appres-*

soria. When fully developed they are dark-coloured and filled with protoplasm from the germ tubes which then appear almost empty (Plate 2, Figs. 10-12). As the germ tubes and appressoria grow, a thin film of mucilage is formed around them causing them to adhere to the leaf or other surface.

The firm attachment of the appressorium to the leaf surface is of the greatest importance because the next stage in development is the formation of a very fine thread at the point of contact with the leaf. This thread forces its way through the outer covering into the leaf. This mode of entry is purely mechanical and if the appressorium were not firmly attached, the pressure exerted would cause it to lift and entry could not be achieved (Plate 2, Fig. 16).

It should be noted that entry into the leaf is gained, not through small pores (stomata) in the leaf surface as was previously supposed (Tunstall and Bose 1921) but forcibly through the cell walls. If entry was always through stomata only, infections would occur almost invariably through the lower surface of the leaf as there are very few, if any, stomata on the upper surface For this reason, when spraying with a fungicide, growers were advised to pay special attention to the lower surfaces of the leaves as that was regarded as the most vulnerable area. In laboratory experiments we find that infection can be obtained through the upper surface as readily as through the lower. When entry is through the upper surface the white blister is still formed on the lower surface. The position of the blister and its sporing surface, therefore, afford no clue as to which surface the fungus entered.

Before describing the further growth of the fungus after entry into the leaves some further information regarding the spores themselves may be of interest.

The spores are relatively short-lived. In the laboratory at St. Coombs they normally remain viable for about a week, but freshly collected spores fail to germinate after exposure to direct sunlight or to a temperature of 35°C (85°F) for one hour. Although fresh spores normally germinate readily under favourable conditions we have on numerous occasions failed to germinate freshly collected spores though spores collected later from the same blisters have germinated normally. The method of germination, particularly the surface on which the spores were placed for germination, was suspect but such abnormal results have been obtained when tea leaf surfaces were used and particular attention paid to water requirements. No satisfactory explanation of these results can be offered though they afford evidence of the existence of an unknown factor deleterious to the spores.

The fact that the spores cannot survive high temperatures suggest that the fungus did not reach South India in the spore form by an overland route from North India. Any spores adhering to merchandise, clothing or such like vehicles would not survive the high temperature experienced during the journey. That probably explains why South India and Ceylon remained free of the disease for so many years. It has already been suggested that the spores reached Ceylon in air currents from South India but a similar explanation of its arrival in South India is not satisfactory because of the failure of the fungus to arrive that way in earlier years.

Because of the high temperatures in the Low-country the disease is unlikely to become a serious pest there. The disease will appear there from time to time when conditions are favourable but it is unlikely to assume the importance it has acquired in the higher districts.

The disease is most prevalent during periods of little sunshine, but its prevalence then is due more to other meteorological conditions, e.g. rain and mist which normally prevail during such periods, than to the absence of sunshine and its disinfecting property. Shade trees, by limiting the amount of sunshine reaching the bushes, may thereby favour the occurrence of the disease but their importance in this respect may easily be overrated.

The time taken for the spores to germinate and gain entry into the leaves or stems varied with external conditions, particularly temperature and the presence of water. In one experiment spores from the same blisters were germinated on glass at 15°, 20° and 25°C. (59°, 68° and 77°F.). The spores germinated best at 25°C ; after 4½ hours fairly long germ tubes were visible whereas the spores germinating at 20°C were just starting to grow. The spores at 15°C did not begin to grow for about 7 hours. The times reported here are, however, not constant as spores have been seen to begin germination in 1½ hours after being wetted at room temperature *(circa* 20°C.).

The time taken for the fungus to gain entry into the tea plant is of interest though it is impossible at present to state with any accuracy the minimum or average times for any set of conditions. The shortest time observed is 8 hours under laboratory conditions with the temperature about 20°C. That observation showed that a few hours of favourable conditions are sufficient to allow infection. When the fungus has entered the host plant external climatic conditions are of little importance for its survival.

The essential requirement for the germination of a spore is water. Spores may find lodgment on suitable leaves but they cannot begin to grow till they are wetted. But very little water is required. In the evening when dew forms, the spores' requirements are fulfilled and growth may start. A few hours later an appressorium is formed from which a penetration tube is sent into the leaf. During this time the germinating spore must be moist. The interval between dew formation and its dispersal next day is often sufficient for the fungus spores to grow and enter leaves as shown by the later formation of blisters. That is to be seen frequently in the fields, most frequently in shaded places. Such observations lead to the conclusion that shade favours the disease.

That conclusion cannot be disputed, though it might be well to consider it in greater detail before remedial measures are based on it. We have seen that shade may prevent the sun from exercising a disinfecting action on the dry spores which may have lodged in the bushes, and that by delaying the evaporation of dew it may prolong the period of favourable conditions thereby allowing more spores to gain entry into the bushes. The times when Blister Blight is most to be feared are when there is little or no sunshine and there is sufficient rain or mist to keep the bushes wet. Then the presence of shade trees is not of the least importance, as they do nothing to increase the incidence of the disease. Shade as a factor affecting the incidence of the disease is, therefore, of importance only at times, in the main, unfavourable to the disease. At such times diseased leaves can be found in shaded areas when less shaded areas are free from the disease.

It may be argued that if the fungus survives in shaded areas at times when it is being exterminated elsewhere by unfavourable conditions, a source for later reinfection of the freed area is maintained. That is true and it would be of greater

importance if shaded areas were the only possible sources for reinfection. The complete removal of shade from all tea areas would *not* result in the eradication of the disease, and should not even be contemplated. It is doubtful that a good case could be made out for the complete removal of shade from any tea area. The benefit derived from shade trees in the form of organic matter for incorporation in the soil as a rule far outweighs the additional Blister Blight damage resulting from their presence. What is required is control and not elimination of shade trees, so that sunlight is admitted into the area at times when it is likely to be beneficial.

After this digression we return to the fungus which has just entered a leaf. A very fine tube from the appressorium has been pushed through the leaf's outer covering, the cuticle and cell wall, and has enlarged to normal thickness within an epidermal cell (Plate 2, Fig 16). At this stage the fungus is independent of external conditions as future growth will be all within the leaf, and the necessary food and water will be obtained there. The tube (hypha) which has entered the epidermal cell continues to grow and leaves the cell without branching. The fungus frequently branches extensively *within* the next layer of cells (Plate 2, Fig. 15) but later growth is almost entirely *between* the cells (Plate 2, Figs. 15-18). By further growth between the cells a more or less large area is invaded. Short irregular branches (*haustoria*) enter the cells and extract nutriment but do not immediately kill them. The cell contents are disorganised, and the invaded area becomes visible as a translucent spot. At the same time the invaded cells are stimulated to further growth — cell enlargement but not division. This causes the invaded area to bulge, usually towards the lower surface and so forms the blister. Translucent spots become visible after about nine days from infection and the blister formation can be dectected a few days later.

A dense growth of hyphae forms under the lower epidermis. Here the hyphae are directed towards the lower surface and are arranged in dense tufts between the cells (Plate 2, Fig. 14). Some of the plant cells are crushed and others dislodged. The leaf's outer skin, the epidermis and cuticle, is broken and flakes off leaving exposed the tufts of hyphae which form the white hymenium. The hyphae which form the hymenium cease growth and become basidia when they produce spores at their extremities. The time from infection till spores are discharged from the hymenium varies from 14 to 21 days, an average time is about 18 days.

The time during which spores are produced from the hymenium varies considerably, it is shortest in very wet or very dry weather but may continue for 7 or 8 days. By that time the invaded leaf cells are exhausted. They die, become black and later fall out leaving a hole in the leaf.

It should be noted that spores are not formed till about 18 days after infection occurred. For that reason fresh blisters may be observed at times when the weather is fine and apparently quite unfavourable for the disease. One has, therefore, to consider climatic conditions about three weeks prior to the occurrence of the sporing blisters. Towards the end of a dry season fresh blisters are usually very scarce and difficult to find. Relatively few spores are in the air and very few find lodgment on suitable tissues. Many are killed by sunlight, by high temperatures or by old age as the spores normally do not survive more than a week or two. Yet a wet day, mist or a prolonged dew which provides enough water long enough

for spore germination and penetration results in a fresh though small crop of blisters three weeks later, no matter what the intervening weather has been like. In this way a very heavy attack can be built up in 8 or 9 weeks. It may build up more rapidly if conditions remain favourable after the first three weeks.

Mention was made earlier of the improbability of spores reaching South India alive by an overland route. But it will be evident that the fungus could be carried across India unwittingly in a living tea plant. We do not suggest that the disease was in fact introduced into South India in that way as we have no evidence of it ; we merely indicate the possibility. It would be equally possible to introduce it into Ceylon in the same way if the plant was smuggled past Customs officials. It is not uncommon to hear grumbles regarding the difficulties of getting plants into different countries. When there are regulations against the import of certain plants there are usually very good reasons for those regulations, hard as they may appear. The regulations are made in the interest of the community as a whole and the planting community in particular, the deliberate breaking of them may prove disastrous.

All tea leaves and stems are not equally susceptible to attack by *Exobasidium vexans*. The older the tissues the less liable they are to infection. The most susceptible are the young leaves enveloping buds ; and it is easier for the fungus to enter a first leaf (counting from the bud) than a second leaf. Usually infections do not occur on the third leaves. This does not mean that blisters are never observed on third or older leaves. They are seen in such positions but the leaves were younger and much nearer the bud when the infection occurred. The interval of nearly three weeks between infection and the complete formation of a white blister must not be forgotten. In that interval several leaves may unfold.

Moreover some bushes are more susceptible than others. Whenever the disease occurs, even mildly, certain bushes display numerous blisters while adjacent bushes are apparently free. On the other hand in heavy infections some bushes carry few or no blisters at the time surrounding bushes are heavily infected. Such bushes should be sought for when the disease is very prevalent and the best of them propagated vegetatively for supplies. The importance of resistant stocks for supplies and replanting needs no emphasis. The search for and propagation of resistant clones is already progressing satisfactorily on many estates.

The fact that young tissues are susceptible whereas old leaves and stems are resistant affords the reason why the time of pruning is of great importance. The reason for the advice that pruning should be timed to obtain a dry weather recovery will be self-evident from the foregoing. The loss of young foliage and stems as a consequence of attacks by this fungus not only results in delay in cropping but may also result in the death of bushes unless they have abundant starch reserves. Successive defoliations would be disastrous. The aim must be to get a cover of resistant foliage as early as possible but that can be done only at times unfavourable to the fungus.

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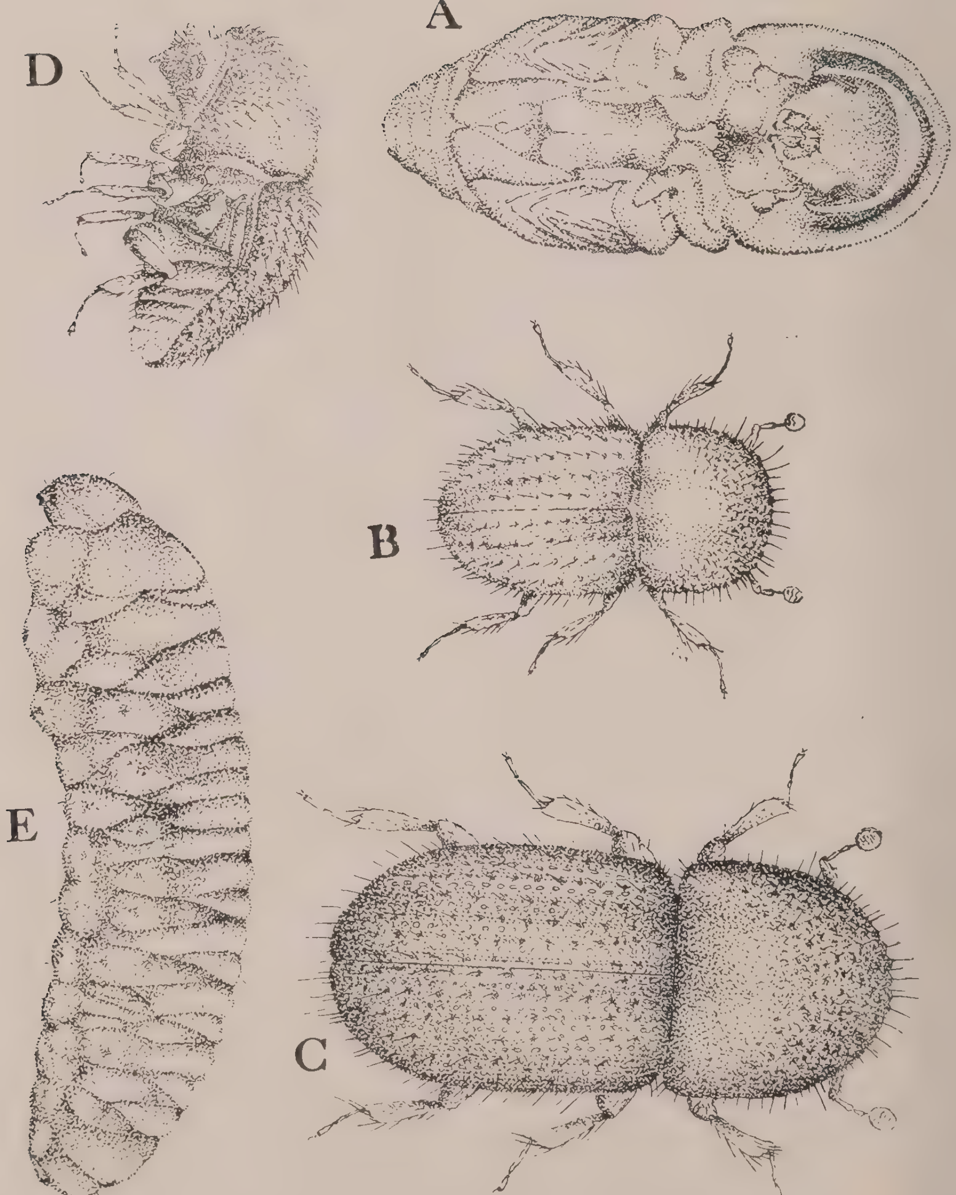

Plate 1. The shot-hole borer of tea (*Xyleborus fornicatus*)
Male B and D. Female C. Pupa A. Larva E.
All x 30. (Drawings by W. T. Fonseka).

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STUDIES OF SHOT-HOLE BORER OF TEA IV—LIFE CYCLE OF THE BEETLE.

C. H. GADD.

In a previous article (Gadd 1941) the life cycle of the shot-hole borer beetle was shown to be made up of the following periods: Pre-oviposition 8.4 days, Incubation 6.9 days, Larval 15.2 days and Pupal 7 days, which together and allowing 2 or 3 days occupation of the old gallery make a total of about 40 days. These observations refer to beetles living at an elevation of 3,500 feet. They were obtained, not by direct measurement of the time stated, but by deduction from data obtained by opening galleries of known ages. Such method had to be used because at that time no means of keeping the insects alive outside their galleries and under conditions allowing direct observation were known. Since then the beetles have been reared under artificial conditions allowing the direct measurement of the various stages of the life history (Gadd 1947). It is therefore of interest to compare the results obtained in that way with those previously published.

Effect of Temperature.—Temperature has a marked effect on the duration of all stages in the life cycle. Within limits, an increase in temperature results in a shortening of the duration of each stage and consequently of the whole cycle. For instance, the pupal period at room temperature at St. Coombs (Altitude 4,500 ft.) occupied 10 days, and at Passara (Altitude 3,500 ft.) 8 days, whereas it was reduced to 5 days by keeping the pupae in an incubator controlled at 82°F. Larvae cannot survive at temperatures much below 60°F and it was difficult to maintain them at St. Coombs where the room temperature fluctuated between 61 and 77°F.

The last observation affords a reason why the beetles fail to become a pest at elevations above 4,000 feet in Ceylon. The beetles, and more frequently their galleries have been found at higher elevations where the temperature is too low for breeding purposes. For instance, when tea bushes on St. Coombs Estate are pruned borer galleries are sometimes found in the branches but these are usually found to be empty. Female beetles undoubtedly arrive on the estate from lower altitudes and make their galleries but the temperature, particularly at night, is too low for survival, especially for the young.

Adults.—The emergence of a female beetle (Plate 1, C) from the gallery in which she was born affords a suitable starting point

for the life cycle. She is then black and equipped for flight with a pair of membranous wings which are normally hidden below hard chitinous covers (elytra). The male is somewhat smaller and having no membranous wings cannot fly. (Plate 1, B and D).

Although capable of flight she seems to make little use of that power. On the wing she may travel considerable distances when aided by wind and so may reach a bush miles away from the infested area. More usually her journey is a short one, sometimes by flight but more frequently by walking. All she seeks is a suitable stem in which to bore and of these there is no shortage. In the laboratory she will re-enter the stem from which she emerged, at a point a few inches away. At one time it was feared that neglected gardens would become breeding places from which the beetles would invade better cultivated areas. Such fears have proved groundless, though not solely because of the beetles' apparent disinclination to fly.

We must assume that when the female emerges from the parent gallery she is already fertilised and that she carries with her spores of the 'ambrosia' fungus which grew on the walls of that gallery. Reasons for these assumptions will become evident later.

On emergence she loses no time in seeking a new home. While outside a gallery she is unprotected against enemies which cannot reach her when within one. The period elapsing between emergence from the parent gallery till a new one is started is the only time during her life when she is normally liable to their attacks. Also she cannot long survive a dry atmosphere. In the laboratory she would live for 2 or 3 days only on dry blotting paper, but if the paper were wetted, she could be maintained for as long as 15 days. Evidently humid conditions, such as occur within the galleries are essential for her well-being. The drier external conditions, however, cannot be the only stimulus which compels her to bore, as, at least in the laboratory, many females which have emerged naturally or been removed from galleries make little or no attempt to bore another, and males never attempt to make galleries.

Having selected a place for entry the female beetle bores rapidly and will make a tunnel equal to her own length in one hour. She continues her tunnelling for 4 or 5 days cutting into the wood with her jaws and pushing the debris from the gallery with the hind end of her body. The gallery is too narrow to allow her to turn, so any unwelcome visitor is unceremoniously expelled in the same way.

Pre-oviposition.—The interval between her leaving her parent's gallery and her laying the first egg is termed the Pre-oviposition period. As no shot-hole borer beetle has been induced to oviposit outside a gallery where she can be observed the only way to determine this period is by opening galleries of known age to observe their contents. The youngest galleries which King (1937) found to contain eggs were 10 days old. A re-examination of his data shows that of nine 10-day old galleries opened, two only contained eggs, and one of them contained four eggs. I have shown elsewhere (1947) that as many as three eggs are rarely laid on any one day, so it is probable that the female with four eggs began to lay not later than the eighth day after commencing to bore her gallery. On the other hand galleries 2, 3 and even 4-weeks old often contain neither eggs nor young, though the female is alive and apparently healthy. In fact it seems probable that many females do not lay eggs although they make the gallery ready for a family.

We can expect our beetle to lay her first egg about 10 days after we first saw her. She did not spend the whole of the pre-oviposition period in boring, as judging by the absence of fresh wood dust below the entrance, the gallery was completed about the fifth day. Near the end of her gallery she has planted the fungus spores brought with her. The fungus garden probably needs little attention, but it is of the greatest importance that the fungus shall flourish if she is to raise a family.

Incubation period.—Her eggs are small glistening ovoid bodies and she deposits them in a heap near the end of her gallery, adding one each day. The fact that eggs are usually found in heaps usually containing not more than seven eggs has given observers the impression that eggs are laid in batches. The eggs, if kept moist on damp blotting paper, will hatch but the eggs of one heap will not all hatch on the same day. Usually the larvae emerge on successive days, though occasionally two and rarely three eggs will hatch on the same day. On some days no eggs hatch. These observations indicate that normally the female lays one egg per day though she may miss some days or lay two or even three sometimes.

How long she will continue to cviposit and how many eggs in all she may be expected to lay are questions to which precise answers cannot be given. As yet a female has not been induced to lay eggs outside a gallery allowing the process to be seen and the eggs counted, so information regarding family size must be obtained by opening galleries. This question will be considered in greater detail in a later article and it will be sufficient to state here that the largest number of young, including eggs observed in a gallery is 35; normally families are very much smaller, and some females have no young. It is unlikely therefore that our beetle will lay more than 35 eggs over a period of 5 weeks.

The incubation of eggs at the Passara laboratories when the mean room temperature is 73°F takes 7 or 8 days. In an incubator at 82°F. the incubation period is shortened to 5 or 6 days. The previous estimate of 6.9 days for incubation, obtained by indirect methods, is therefore not improbable.

An incubation period of seven days coupled with the fact that the females normally lay one egg per day affords an explanation why the egg heaps rarely contain more than seven eggs. Larger heaps are indicative of abnormal egg laying, and smaller heaps, which are much more frequently encountered, result from irregular oviposition during the previous week.

Larval period.—The newly hatched larva is a small white worm-like object and extremely hungry (Plate 1, E). When placed on cultures of the ambrosia fungus *Monacrosporium ambrosium* (Gadd and Loos 1947) they immediately begin to feed ravenously and continue to do so, except for short periods while moulting, until they are full grown and ready to pupate. This fungus occurs naturally on the walls of borer galleries and is undoubtedly transplanted there by the parent females though how or where it is carried is not definitely known. The fact that the insects can be maintained through their whole larval period on pure cultures of the fungus is a clear indication that it forms the main, if not sole, essential food.

The dark purple stain in the tissues around the beetle's gallery is due to this fungus which normally excretes a coloring matter. The fungus extracts its nutriment from the stem tissues, and fruits on the gallery walls giving them a frosted appearance. The larvae feed on the spores. The

importance of the fungus in the insect's economy and the amount and nature of the work to be done before it can be planted in a suitable place for growth seem to rule out the possibility that transfer is entirely accidental.

When the insects are kept in artificial culture the full larval period, from egg-hatch to pupation, is very variable and markedly influenced by temperature. At St. Coombs when the room temperature varied from 61°to 77°F. with a mean daily temperature of 68°F. the shortest larval period observed was 18 days and the longest 33 days. The mean of eight larvae was 23.6 days, and some larvae lived as long as 40 days without pupating. Deaths were very numerous. Better results were obtained when the cultures were kept in an incubator at 77°F or 82°F. At 82°F. the larval period varied from 9 to 19 days; the mean for 31 insects was 12.4 days which is approximately half of that at room temperature. The larval period previously determined statistically from data of galleries collected and opened at Passara was 15.2 days, which when compared with the above observations appears tolerably correct.

The larval period can be divided into 3 parts separated by moults. The first stage (or instar) is completed about the end of the second day when the larva stops feeding and becomes quiescent. After casting its skin it again becomes active and voracious. The second moult occurs after about the seventh day or later and the final one at pupation on the tenth day or later.

The most critical period in the insect's life appears to occur at the first moult when in artificial cultures deaths are most numerous. Changes in the technique failed to reduce the number materially. In this connection it may be noted that in the earlier investigation dealing solely with data collected from the field it was noted that "only 50 per cent. of the eggs laid develop into adults." The numerous deaths noted in artificial cultures cannot therefore be ascribed solely to faulty technique nor to the absence of maternal care. The experiments show when the deaths are most likely to occur, viz. at the first moult.

Pupal Period.—For one or two days before pupation the larva lies on its back and becomes quiescent. This is usually known as the prepupal period but in this account it has been counted as part of the larval period.

The length of the pupal period varies from 5 days at 82°F. to 10 days at room temperature at St. Coombs (*Circa* 68°F.). Our previous estimate was 7 days which agrees tolerably well with the period ascertained in the Passara laboratories, viz. 8 days.

Two or three days before the adult emerges from the pupal case the mouth parts and eyes become black. The true wings of females, but not the elytra, also become dark coloured, and so at this stage sex can be determined as the males having no true wings do not exhibit this coloration along the body.

Adults.—The adults on emerging from the pupal case are pale yellow except for the eyes, mouth parts and true wings. Colour development in adults raised in culture is slow and at least 5 or 6 days will elapse before the beetles are fully black. As the beetles are black when they leave the gallery it is evident that they remain in it for at least 5 days after emerging from the pupal case. This view is supported by the fact that several young adults are sometimes found together in a gallery.

The male to female ratio of beetles in tea stems is 1:4 or 5 and in castor stems it is probably much wider. Green (1903)

expressed the view that mating occurs within the gallery, and such evidence as there is points to that conclusion. The main difficulty in accepting it is the failure to understand how copulation can occur within the gallery because its diameter is too small to allow one adult beetle to pass another. Also there are no special places of greater diameter or height which might serve as nuptial chambers.

In laboratory cages males are frequently seen walking on the stems and they have been observed to follow young females into galleries recently excavated. It cannot be suggested however that copulation takes place in new galleries as the same objections must be raised to that locality as to the old galleries. Moreover when females fly to a new area the males being without wings cannot follow and so if copulation normally occurs in new galleries such females would invariably be infertile.

Males from castor stems have been observed in the laboratory to excavate shallow chambers adjoining the gallery entrances and to lie in them as though 'in wait.' Not all males do so nor does every gallery entrance have a 'male cavity' adjoining it. These observations suggest that copulation may occur at gallery entrances but such has not been observed. Similar cavities have not been found at gallery entrances in tea stems. Mating has not been observed in cultures and there is doubt that females under those conditions have ever been fertilized.

In the absence of evidence to the contrary we must assume that copulation normally occurs within the parent gallery. Yet the conditions there and the frequency of small families which do not always include a male suggest that many female borers are not fertilised on emergence and consequently have no young. The existence of numerous galleries which do not contain young or eggs is probably to be accounted for by the absence of fertilisation.

The parent female remains mistress of the gallery until all her young have departed. She dies sometimes later but her gallery is never used again for breeding. Each female makes her own gallery and on her death the gallery remains empty.

Life Cycle.—With the emergence of a daughter beetle from her parent's gallery the life cycle is completed. The cycle at 3,000 to 3,500 feet would occupy 6 or 7 weeks made up as follows :—

Pre-oviposition	...	10 days
Incubation	...	7 days
Larval period	...	15 days
Pupae ...	...	8 days
Adult (before leaving gallery)		5 days
Total	...	45 days

Although the eldest of the family may emerge about 6 or 7 weeks after the mother began the construction of her gallery the youngest will not leave till some weeks later, depending on the size of the family and the intervals between egg-laying. By the time the youngest leaves, the eldest female may have a family of her own. In the field young females leave the parent galleries every day and so any increase in the beetle population is a gradual process and not one of marked steps at intervals of 6 or 7 weeks.

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STUDIES OF SHOT-HOLE BORER OF TEA V.—BORER POPULATION.

C. H. GADD.

The work of an economic entomologist is largely concerned with insect populations though the fact is often camouflaged. Usually, his object is either to reduce a population to a minimum or maintain it at a maximum, depending on whether the insect is a pest or of value, like silkworms. When the insects are visible, marked changes in their numbers become obvious without counting, and should numbers be required enumeration is relatively simple. Borer beetles are rarely seen and consequently little is known about fluctuations in their numbers. Gallery entrances are fairly obvious and it might be assumed that their number bears a direct relationship to the beetle population, but it is now known that bushes will contain numerous galleries when the beetle population is very small.

Methods.—The first attempt to estimate the borer population in experimental plots was made by Jepson (1922) in order to assess the effect of manures. For obvious reasons the counting of all beetles in his plots was a well-nigh impossible task, so a method of sampling had to be resorted to. He therefore, selected at random a number of bushes in each plot and counted the gallery entrances, and by opening some of the galleries he ascertained the number of insects within them. An estimate of the total population could be obtained by multiplying the number of galleries by their mean content. As the bushes were examined *in situ* and relatively few branches were removed to ascertain the mean gallery content, the damage caused to the tea was small. The counting of gallery entrances in the field, however, involved considerable labour and discomfort and the error resulting was undoubtedly large.

King (Gadd 1942) improved on this method by pruning sample bushes and counting the galleries and beetles in the prunings. In this way the error is undoubtedly decreased but the temporary damage to the tea is tremendous, as by the end of an experiment the area contains bushes at different ages from pruning, and a few years must elapse before the area can become uniform again. Obviously such treatment cannot be superimposed on a long term manurial experiment without causing considerable inconveniences. This method was used with advantage to determine the relative effects of light and hard plucking on the beetle population.

In order to avoid these disadvantages a third method has been tried. Instead of taking a given number of bushes as a sample, only such branches as are broken during plucking and other cultural operations or by natural means such as by the wind are used. The method allows of a thorough examination of the material without causing any extra damage to the bushes, but at the same time it introduces other disadvantages, the most obvious of which is the variation in the size of the sample from time to time. The largest samples are collected at times when damage is greatest.

The number of broken branches in the sample affords a measure of the damage done, and, if as is usually the case, damage is proportional to the size of the population causing it, then the variation in the numbers of broken branches will indicate the fluctu

ations of the beetle population. If that assumption is true, it will be obvious that the counting of broken branches will be the simplest method of determining the fluctuations in beetle numbers. But the damage to a borer infested bush depends not only upon the number of galleries or beetles but upon the treatment the bush is subjected to. For instance if a stick is drawn over its surface more branches break than if the bush is not so roughly treated. Sufficient branches break during normal plucking operations to make unnecessary the use of other methods to cause breakages. But when other works are undertaken or strong winds are prevalent extra breakages, which cannot be estimated accurately, will occur Also a breakage depends upon the existence of a gallery. That gallery may be empty or it may be occupied by a family of beetles. So it would appear that the number of breakages would depend more upon the number of galleries than upon the actual number of beetles in the bush at the time. It becomes evident therefore, that any assumption of damage being proportional to population needs verification before acceptance.

The problem.—During the 3-year cycle (1940-43) in an area of tea in the Passara district records were collected weekly of the damage occurring as represented by broken branches. The records showed that the damage followed a definite pattern. At the beginning of the cycle broken branches were few but towards the end of the first year and more markedly in the second year they became more numerous until a peak was reached near the end of the year. Early in the third year damage decreased and finally became relatively stable at a low level. Our problem is to determine whether the beetle population followed a similar course

Records of broken branches were collected from the same area during the cycle 1943-46 with the object (1) of determining whether a similar course of events would occur and (2) of ascertaining whether the beetle population fluctuated in a similar manner. The experimental area is 3.2 acres in extent and is laid out primarily as a long term manurial experiment, on which the pruning of bushes at intervals for estimations of beetle population could not be allowed ; so the best had to be made of broken branches for that purpose At three-week intervals the broken branches were dissected and records made of the galleries and insects within them (Table 3).

Before attempting to interpret the results certain sources of error must be mentioned. When broken branches are collected after plucking some are apt to be overlooked. At the next collection such branches are obvious because of their dried leaves. Each collection, therefore, consisted of dried and fresh branches, the dried ones really belonging to the previous week's records At first no great importance was attached to this source of error until it was ascertained that the galleries in the dried branches invariably contained fewer insects than the fresh ones. Evidence was obtained that during drying many adults left the galleries and many larvae died. From February 21st, 1945, onwards, the fresh and dried branches were separated and although the total was entered in the records as broken branches, only freshly broken branches were used for the determination of insect numbers. The values given before that date for total occupants and mean contents per occupied gallery are probably somewhat under-estimated

Fractures always occur at a gallery and such broken galleries are referred to as "Galleries at the break" to distinguish them from "Galleries in the branch" which are not so damaged. There is of course a risk that some insects are lost from galleries at the break and these were therefore not used

at any time for the estimation of beetle contents. They are, however, included in the estimate of "Galleries per branch."

Beetle Counts.—The simplest and most direct way of estimating the size of a population is by counting heads The number of beetles in all stages of development found in the broken branches on each occasion is given in Table 3 under the heading "Gallery contents." The number increased until May 16th and then declined. But on May 16th there were more branches to be examined than at other times so the larger number of beetles counted then may be due solely to the larger sample from which the beetles were taken. A much better estimate of a beetle population was made by King when determining the effect of hard plucking on the beetle population. His data have already been published (Gadd 1942) and a part of them is produced here as Table I for easy reference. It will be seen from that table that the population steadily increased from 14 per bush in the 19th month from pruning to 87 per bush in the 23rd month. No further records were taken till the end of the third year when only 7 or less per bush were found These figures clearly indicate a steady increase during the second year and a marked decrease in the third year though the time of the change cannot be ascertained.

Gallery Counts.—The same data also show that the number of galleries per bush increased from 3 to 25 between the 19th and 23rd months from pruning and that at the end of the 3rd year they numbered about 100.

A borer-infested tea bush is rather like a town of which the beetle galleries are the houses. The citizens of that town live mainly indoors and are rarely seen in the streets. They also have other curious characteristics. When the young females become adult they leave home and build new houses in which to raise their families; the result is that the town increases in size but the empty houses become more numerous also. To an observer the town would appear large if the houses are numerous; but to get any idea of the condition of the population he must note the number of new houses being erected. If they are many, the population is thriving; but if they are very few the town is dead. When once a house is made it remains as part of the town and so the town never diminishes in size even if the population becomes extinct. The size of the town therefore represents the summation of its history; the new houses only represent current times.

Applying these principles to the above figures it becomes evident from the increasing number of galleries in the second year that the population is thriving; and that conclusion is verified by the increase in the population at that time. At the end of the third year although galleries are numerous the population cannot be large because new houses are very scarce and difficult to find. Those observations indicate that the population is either extinct or very small in number. That conclusion is again confirmed by the actual count of the inhabitants.

Turning now to the 1943-46 data in Table 3 the number of galleries per broken branch is given at each examination; the galleries at the break are included in these estimates. The number varies from rather more than one to less than three but there is no indication of a steady increase from a low to a high value as would be expected. Beetles were undoubtedly living in the infested bushes during the whole period and new galleries were undoubtedly being made. It becomes evident, therefore that the method of sampling is entirely unsuitable and will not allow the fluctuations in the beetle population of the area being determined either from the number of galleries or the number of beetles in broken branches.

Before abandoning the data as being of no value it is necessary to ascertain whether the records do not give the information required in other ways

Natural Balance.—The rate at which a population can increase will depend upon (1) the length of the life cycle of the insect, (2) the number of young each female can produce, and (3) the sex ratio These data give the *Reproductive potential* which may be defined as the number of female descendents produced by one pair of insects in a given period under conditions ideal for breeding and survival. For instance Tea tortrix (*Homona coffearia*) at St. Coombs produces 5 generations in a year, the female can lay 500 eggs of which about half are males. Each generation could, therefore, be 250 times greater than the preceding one. At that rate the offspring of a pair of moths would number thousands of millions at the end of one year.

Obviously the reproductive potential tells nothing of the real rate of growth of an insect population under natural conditions It merely tells what can happen when circumstances are favourable, but it affords an explanation of why certain insects with a high potential suddenly become very numerous at times. The reproductive potential is a measure of an inherent character or force always tending to increase the population numbers. Counteracting that tendency are a number of destructive factors such as unfavourable temperature humidity, parasites, disease, shortage of food, etc., which together form the controlling factors of the environment. The resultant of these two pressures, the reproductive potential on one side tending to increase numbers, and the controlling factors on the other tending to reduce them, is a balance sometimes known as the *Natural balance.* In an unchanging environment the population would remain numerically unchanged and the beam of the balance would remain stationary. But although the reproductive potential is constant, the environment is always changing. The weather may become less favourable, the destruction of the host plants by the insects themselves may result in famine ; over-crowding may cause disease epidemics ; all result in a decreasing population. The beam of the balance is, therefore, rarely stationary, it swings up and down as the environment changes The movement is so continuous that the term balance seems a misnomer.

No accurate estimate can yet be given of the reproductive potential of shot-hole borer, except to say that it is very small when compared with that of Tea tortrix (given above) and most other insects. Its life cycle occupies 6 or 7 weeks which allows of 7 or 8 generations per year, and the male to female ratio is usually 1:4 or 5 though at times it may be narrower than that. But little is known about the number of eggs a female is capable of laying under most favourable conditions. This cannot be ascertained merely by opening galleries and counting their contents. When a gallery is opened it is impossible to tell whether the parent has laid her full compliment of eggs, or whether some individuals have died or have left the gallery on completion of their development.

Gallery Contents.—A very large number of galleries were opened during the 1943-46 plucking cycle to ascertain their contents. In Table 2 is given a summary of examinations made weekly during the period May 16th to August 1st 1945 when the bushes were nearing the end of the second year from pruning and damage in the plots was at its maximum.

2,766 galleries contained beetles and rather more than half of them contained one only, the parent female. Some of those

which contained the parent only were no doubt less than 10 days old and would not, therefore, be expected to contain eggs or young, but it is very unlikely that fifty per cent of the galleries were less than 10 days old. We know that the eldest of a family is not likely to emerge till the gallery is 45 days old and the youngest some time later depending upon the number of eggs laid and the intervals between oviposition. If we assume that the occupied galleries varied in age from 1 to 50 days we should not expect much more than 1/5th or 20 per cent. of them to be less than 10 days old and, consequently, without young. Those figures lend support to the view expressed in an earlier section that many females fail to produce a family, possibly because they are not fertilised.

The galleries contained, in all, 9,714 insects which gives a mean content of occupied galleries of 3.5 individuals of which 2.5 are young. If, however, we exclude from the calculation those galleries which contain an adult female only, the average family size becomes 6.1 of which 5.1 are young. The term 'average family size' has been used here in contradistinction to 'mean contents' which is determined from all occupied galleries no matter whether they contain young or not.

It may be seen from Table 2 that the size of individual families varies very considerably though the majority includes five young or less. Two galleries contained more than 30 young; that demonstrates the ability of some females to lay at least 30 eggs The average size of a family as determined in this way depends on several factors of which one is the average age of the galleries. As the gallery ages after 10 days the number of inmates increases until the young begin to emerge, after which the number decreases. For this reason and others it has not been found possible to determine the average age of a sample of galleries from its contents

Family size also appears to be dependent to some extent on the location of the gallery. As a general rule the largest families were found in galleries made in the pith and at points where a branch forked. As the gallery is an important part of the beetle's environment any changes in that environment will be reflected in population numbers, possibly in family size and mean content.

That hypothesis can be tested. We have already seen that during the twelve week period May 16th to August 1st, 1945 the mean content of the occupied galleries was 3.5. That period can be divided into two equal parts and the mean content of occupied galleries determined separately. During the six week period May 16th to June 20th. 1569 occupied galleries were opened and the inmates ascertained to number 6286 giving a mean content of 4. During the second six week period terminating on August 1st the corresponding figures were 1197 galleries, 2428 inmates and a mean content of 2.9. It would appear, therefore, that a change detrimental to the beetle had occurred as shown by the fall in mean content of occupied galleries from 4.0 to 2.9 and that in consequence a future decrease in the amount of damage to the plots may be expected. After August 1st the number of broken branches in the plots did decrease as may be seen from the records shown in Table 3. King's data in Table 1 also show smaller mean contents of occupied galleries in 1941 than in 1940.

In Table 3 the mean contents of occupied galleries as determined at each examination are given, but there is no evidence there of any obvious change in family size. It seems doubtful, therefore, that any great reliance can be placed on mean contents of occupied galleries as a means of measuring

the fluctuations of the borer population or of forecasting the degree of future attacks. The large variation in the number of young in individual galleries makes a large sample essential for an accurate estimation of their mean contents, and it is probable that the great variation of the means shown in Table 3 is due largely to the samples not being sufficiently large. If heads have to be counted a method of sampling like King's, using whole bushes as units, must be resorted to, so that absolute figures can be used. Other methods, however, remain to be tested.

Net Reproduction Rate.—If a community is to replace itself every potential mother must, on the average, produce at least one daughter. Unless this happens no reduction of mortality can save the community from eventual extinction. Moreover, if the community is to survive that daughter must reach maturity and in her turn produce, on the average, at least one daughter. Viewed in this way it is evident that survival depends upon the female of the species, not merely on the number born but on the number that survives and carries on the functions of reproduction. So long as every mother of one generation is merely replaced by another in the following generation the population will tend to remain constant, when the net reproductive rate is said to be 1. If this rate has a higher value the population will increase. For instance, for the net reproduction rate to be 2 there must be two mothers for every one of the preceding generation and each must, on the average, have two daughters who in turn will have similar families. Each generation then will be twice the size of the preceding one.

The net reproductive rate is one of the most important statistics concerning any population as it affords a measure of the rate of increase in the population. It will be noted that it concerns mothers only and is quite independent of birth or death rates; it is the resultant of inherent reproductive capacity of the insects and the opposing forces of the environment; thus, it is a measure of Natural balance. A true balance occurs only when the net reproduction rate is 1 as then the population neither increases nor decreases from generation to generation.

Percentage of occupied galleries.—As each gallery is made by a potential mother borer the number of galleries within a bush provides a record of all mothers, past and present, that have used the bush for breeding since it was last pruned. The occupied galleries each contain a mother or potential mother, so an estimate of the number of mothers in the current generation can be obtained. Let us assume that 50 per cent. of all the galleries are occupied. That means that the existing population of mothers is equal in number to all the mothers in past generations that have used the material examined for breeding purposes. Obviously the population has been steadily increasing. In order to ascertain what effect the net reproduction rate will have on the percentage of galleries occupied let us suppose that the rate is 2 and that it will be so maintained during the next few generations. We can represent the percentage of occupied galleries by the fraction ½ the numerator being occupied galleries (or mothers) and the denominator all galleries. In the next generation the one mother will be replaced by 2, and 2 new galleries will be made. The fraction then becomes 2/4 or still 50 per cent This process can be repeated any number of times without altering the percentage. Now suppose that the net reproduction rate increases to 4 while the percentage of occupied galleries is still 50. The fraction representing the present generation is still ½ but those representing future generations in succes-

sion become

4/6 (67%), 16/22 (73%), 64/86 (74%)

The percentage is gradually approximating 75 per cent,* at which it will become stable. An increasing percentage therefore indicates an increasing rate of reproduction and a decreasing percentage can be interpreted as indicating a diminishing rate until that rate is 1. When the rate remains at 1 and the beetle population in consequence remains stable, the percentage of occupied galleries will continue to fall slowly until after many generations it would become so small as to approximate 0. A net reproduction rate of less than 1 would result in a more rapid decrease in the percentage of occupied galleries.

The percentages of occupied galleries determined at intervals during the cycle 1943-1946 are given in Table 3. Until November 22nd, 1944 (near the beginning of the second year) the percentage fluctuated between 60 and 70 indicating a net reproduction rate of about 3. During this time an appreciable population was being built up from relatively few beetles until the damage in the plots began to be measurable. Between November 22nd, 1944 and August 1st, 1945 (near the end of the second year) the percentage fiuctuated between 40 and 50 representing a net reproduction rate between 1.6 and 2.0 which indicates that the beetle population was continuing to increase though less rapidly than previously. In consequence of the growing population broken branches increased in number till more than 700 were being collected weekly. After August 1st, the percentage of occupied galleries fell rapidly until by December 19th, only 5 per cent. of the galleries were occupied. This can only mean that the net reproduction rate had fallen below a value of 1 and in consequence the beetle population was dying out. This conclusion is supported by the fact that the damage decreased until between 100-125 broken branches only were collected from May 15th 1946 onwards.

The data in Table 1 tell the same though less complete story. During the first part of that experiment until the bushes were 23 months from pruning the percentage of occupied galleries, though decreasing, was never below 50 which clearly indicates a growing population. During the second part of the experiment, at the end of the third year, the percentage was never above 2. Although that value of itself does not indicate a net reproduction value of less than 1 and a fall in population numbers, the fact that the population was 7 or less per bush during that period is clear proof of the decrease in population.

There is clear evidence, therefore, that the beetle populations in both experiments were affected similarly. The 1943-46 experiment, however, shows more clearly that the net reproduction rate after the first few months decreased steadily throughout the cycle until by the beginning of the third year it had fallen below a value of 1, and the population in consequence was almost extinguished.

Percentage Healed Galleries.—Some time after the galleries are empty the entrances become obliterated by the growth of new tissues which completely block the aperture. Such galleries are known as healed galleries. The number found at any examination can be expressed as a percentage in the same way that the percentage of occupied galleries can be determined. The question arises whether fluctuations in the net reproductive rate is also reflected in the

* A simple formula for determinating the value at which occupied gallery percentages will stabilise for a given net reproduction rate is :-

Percentage of occupied galleries $= \frac{100 (r = 1)}{r}$ where r is the net reproduction rate.

percentage of healed galleries. The counting of healed galleries in prunings or broken branches in the laboratory is far less laborious than the counting of occupied galleries because the necessity for dissecting galleries to ascertain their contents is eliminated.

The healing of galleries was discussed in part 2 of these studies (Gadd 1947) and it was there shewn that estimates of the time taken for galleries to heal varied from 3 to 5 months. For our purpose here it will be necessary to convert that period into terms of beetle generations ; so the period from the beginning of boring to the healing of the gallery becomes equal to 2 to 3 beetle generations.

Let us assume a net reproduction rate of 2, a period of healing equal to 3 generations. If the net reproduction rate has been maintained at 2, 50 per cent of galleries will be occupied. We can represent the occupied galleries in successive generations, as before, by the fractions.

1/2 ; 2/4 ; 4/8 ; 8/16 ; 16/32, etc.

In the first generation there are two galleries for every one occupied by beetles. Three generations later those two galleries will be healed, but the total galleries will number 16 of which 8 are occupied. If we now write the fraction with healed galleries instead of occupied galleries as the numerator it becomes 2/16 and the percentage of healed galleries is, therefore, 12.5. Similarly the 4 galleries of the second generation will be healed 3 generations later when there are 32 galleries in all and the fraction representing healed galleries becomes 4/32 or 12.5 per cent as before. So long as the net reproduction rate remains at 2 the percentage of healed galleries is stable at 12.5 per cent. If we change the net reproduction rate from 2 to 3 we can write the successive fractions for occupied galleries as

1/2 ; 3/5 ; 9/14 ; 27/41 ; 81/122 ; 243/365, etc.

and for healed galleries at the fourth and successive generations as

2/41 (4.9%); 5/122 (4.1%);
14/365 (3.8%), etc.

stabilising around 3.7%.* An increase of the net reproduction rate, therefore, results ultimately in a decrease in the percentage of healed galleries.

Similarly, increasing percentages of healed galleries indicate a decreasing rate of reproduction until the net reproductive rate becomes 1 and then, although the population remains constant in number, the percentage of healed galleries will increase slowly. A diminishing population can only be detected by a more rapid increase in the percentage of healed galleries.

The story given by the percentages of healed galleries in Table 3 is much the same as that told by the occupied galleries. Until the end of November 1944 the percentage of healed galleries remained low ; by March 1945 it had risen to about 30 per cent. where it remained till the beginning of October 1945 ; later it rose rapidly and fluctuated at about 80. The story is that of a decreasing net reproductive rate and although there is no definite means of determining exactly when it fell below a value of 1 the increase in the percentage of healed galleries from the end of October 1945 suggest that it occurred 2 or 3 months earlier.

Conclusions.—The story disclosed by this study of the borer beetle population is one of a decreasing rate of

* A formula for determining the value at which healed gallery percentages will stabilise is :-
Percentage of healed galleries $= \frac{100}{rt}$ where r = the net reproduction rate and t the time of healing expressed in terms of beetle generations.

reproduction. At the beginning of the cycle conditions are at their best for the beetles and the population increases at a rapid rate. Initially the beetles are few and some time is taken to build up an appreciable population. About the end of the first year conditions begin to become less satisfactory and the net rate of reproduction decreases gradually. Nevertheless, the population continues to grow for a time and then is only able to maintain itself at a level. At this period the maximum amount of damage will be done in the plots as the population is at its maximum. Conditions continue to grow worse as from the 23rd month onwards there is a rapid decrease of occupied galleries and similar rapid increase of healed galleries about 3 months later. The decline of the population is as rapid as its growth if not more so and by the end of the third year the population may be almost extinct.

There can now be no doubt that the increase of damage in the second year and its decrease in the third is due entirely to the growth and decline of the beetle population.

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TABLE I.
Beetle Population in Plucked Bushes.
(King's data from T.Q.XV. P.34, Table I)

Date		Month from pruning	No. of bushes	Type of Gallery						Galls per bush.	Gallery Contents	
				Healed		Empty No.	Occupied		Total No.		Per bush	For occupied gallery
				No.	%		No.	%				
1940												
July	24	19	30	9	9	21	65	68	95	3	14	6·5
Aug.	15	20	30	17	11	44	99	62	160	5	20	6·0
Sept.	5	21	30	19	10	44	118	65	181	6	23	6·0
Sept.	24	21	30	38	11	42	253	76	333	11	46	5·5
Oct.	16	22	30	65	12	157	340	60	562	19	80	7·1
Nov.	6	23	30	69	13	184	285	53	538	18	62	6·5
Nov.	29	23	30	116	16	255	377	50	748	25	87	7·0
1941												
Oct.	9	34	12	894	74	293	19	1·6	1206	100	5	3·4
Oct.	23	34	9	501	72	193	3	0·4	697	77	1	1·7
Nov.	5	35	12	871	78	229	19	1·7	1119	93	5	3·4
Nov.	19	35	12	869	85	145	8	0·8	1022	85	2	2·9
Dec.	3	36	11	971	88	111	22	2·0	1104	100	7	3·9

TABLE II.
Frequency Table of gallery contents during the period May 16th—August 1st, 1945.

	Contents	Frequency	Percent	Contents	Frequency	Percent
	1	1408	50·9	17–21	33	1·2
	2–6	907	32·8	22–26	4	0·14
	7–11	304	11·0	27–31	3	0·11
	12–16	105	3·8	32–36	2	0·07
Total	—	—	—	—	2766	100·02

TABLE III.

Data collected from broken branchcs during the cycle 1943-1946.

Date	Month from pruning	No. of broken branches	Galleries per branch	Galleries in Branch: Occupied No.	Occupied %	Healed No.	Healed %	Total	Gallery contents: Total	Per occupied gallery.
1944.										
June 7	9	108	1·17	14	78	2	11	18	69	4·9
28		93	1·30	16	57	6	21	28	39	2·4
July 19	10	225	1·44	42	62	5	7	68	104	2·5
Aug. 9	11	314	1·26	58	71	6	7	82	205	3·5
30		314	1·50	67	71	3	3	95	259	3·9
Sept. 20	12	245	1·39	66	69	9	9	96	247	3·7
Oct. 11	13	355	1·45	106	67	13	8	159	441	4·2
Nov. 1	14	277	1·49	79	59	12	9	135	228	2·9
22		338	1·65	138	63	19	9	220	681	4·9
Dec. 13	15	344	2·26	113	54	22	11	209	613	5·4
1945.										
Jany. 3	16	469	1·83	194	50	72	19	388	1075	5·5
24		439	1·75	147	45	58	18	326	632	4·2
Feb. 21	17	559	1·70	127*	48*	73*	27*	267*	492*	3·9*
Mar. 14	18	451	2·20	176	34	178	34	523	773	4·4
Apl. 4	19	602	1·93	208	42	148	30	491	1395	6·7
25		508	2·30	249	41	229	38	607	1448	5·8
May. 16	20	1125	1·78	361	55	171	26	660	1465	4·1
June. 6	21	716	1·79	189	44	136	32	428	758	4·0
27		711	1·71	176	53	81	24	331	529	3·0
July. 18	22	821	1·77	182	39	136	29	465	404	2·2
Aug. 1	23	806	1·86	228	42	151	28	543	792	3·5
22		779	1·88	188	34	172	31	561	767	4·1
Sept. 12	24	660	2·69	151	31	161	33	482	569	3·8
Oct. 3	25	505	1·89	72	20	128	35	361	233	3·2
24		495	1·91	42	11	242	62	388	133	3·2
Nov. 14	26	451	2·04	46	10	272	58	467	233	5·0
Dec. 5	27	480	2·24	44	8	386	70	555	204	4·6
19		392	2·32	25	5	388	77	505	143	5·7
1946.										
Jany. 9	28	364	2·19	31	8	288	72	400	112	3·6
30		337	2·70	42	7	455	80	572	213	5·1
Febv. 20	29	316	1·59	27	5	435	79	549	136	5·0
Mar. 13	30	290	2·76	32	6	374	78	503	139	4·4
Apl. 3	31	239	2·80	25	6	315	73	430	80	3·2
24		135	2·78	22	9	189	79	238	86	3·9
May. 15	32	97	2·16	13	12	96	86	112	101	7·8
June. 5	33	125	1·92	20	18	71	66	107	51	2·6
26		127	1·85	25	29	51	69	87	122	4·9
July. 17	34	109	1·83	31	26	42	48	87	117	3·8
Aug. 7	35	126	1·81	19	23	56	69	81	104	5·5
28		118	2·00	30	26	70	61	115	112	3·7

*From February 21st, 1945, onwards, determined from fresh branches only. See text.

BLISTER BLIGHT — A REVIEW*

By

G. B. Portsmouth, Plant Physiologist,

and

C. A. Loos, Acting Plant Pathologist.

INTRODUCTION.

In October, 1946 Blister Blight was reported from an estate in the Dolosbage district of Ceylon. This incidence of the disease followed close on its observance in the tea districts of South India. In a short space of time the attack spread through the tea areas receiving the South West monsoon while at the end of 1946 areas subject to only the North East rains received their first visitation of the fungus. Since then probably every tea estate has had its attacks which may occur as light or heavy infestations dependant on climatic or environmental conditions. Much has since been written and said both of the disease and its control. When the disease first became general in our tea areas instructions on control measures had to be based on the evidence collected from other countries where it had been known for many years. Many of these recommendations, in the light of further knowledge, have been found to be impracticable under the varied conditions in which Ceylon tea is grown. The time appears opportune now to sort out the evidence we have accumulated bringing together in one publication the observations we have made and the control measures now advocated by this Institute.

We will be failing in our duty if we do not record the vast amount of time and energy spent by two former officers of this Institute, Dr. Gadd and Dr. Tubbs, on whose shoulders rested the responsibility of advisory and research work in connection with the then new disease.

In addition to addresses at the many Planters' Association meetings a number of publications on Blister Blight have been issued. A list of these publications is given at the end of this review.

THE FUNGUS AND ITS DISTRIBUTION

No adequate control measures on any fungal disease is possible without a full knowledge of the morphology and life history of the causative fungus. Such work is often arduous and long, especially with an obligate parasite, when cultural growth on synthetic media is impossible. It became evident very soon after this work was commenced that previously published data left much to be desired. In consequence the work undertaken had to be as full and comprehensive as possible. Though much of this work has been of academic interest it was essential as a basis in the adoption of control measures. In a review such as this no useful purpose can be served by mentioning the points of scientific interest we have established. Two papers dealing fully with this matter have been accepted for publication (Gadd and Loos 1948 and 1949) in a scientific journal while a publication of more popular interest to planters appears elsewhere in this issue of the "Tea Quarterly."

Elevation plays an important part in the severity of the disease. Below about 1,000 feet Blister Blight is of no economic importance; extensive control measures on estates below that elevation are, therefore, unnecessary. At higher elevations severity of attack depends mainly on climatic conditions. Fields and valleys over which mist

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* **Editor's Note.**

This article which was published as a circular in June 1949 should be read in conjunction with the addresses given by Dr. R. V. Norris and Mr. J. Lamb to the Standing Committee for Agency Affairs reported on page 48.

persists for fairly long periods suffer more severely than those areas over which these conditions do not usually prevail.

Our experimentation has revealed that a blister spore is relatively short lived. Under dry but shady conditions they remain viable for about a week. However, spores exposed for one hour to direct sunlight or to a temperature of 95°F. fail to germinate. This probably accounts for the failure of Blister Blight to establish itself in the low-country.

Previous work in other countries suggested that entry of the fungus into a tea leaf was *via* the stomata (breathing pores) which are located on the under-surface of the leaf. Research work in this laboratory has proved that entry is mainly through the leaf cuticle on either the upper or lower surfaces of the leaf and that there is no stomatal attraction. Further, 8 hours has been found sufficient for germination and entry into the leaf. During the whole of this time moist, sunless conditions must exist but once penetration has occurred the fungus is able to establish itself whatever conditions may prevail outside the leaf.

CONTROL MEASURES

As stated many times before it is unlikely that *eradication* or *cure* of Blister Blight will ever be possible. Bearing this in mind emphasis has to be laid on control. The more one sees of the disease the more evident is the effect of local conditions on its severity. For this reason control may only be achieved by a combination of several measures which may vary from estate to estate and even from field to field.

The three main forms of control applicable are :—

(1) Protection of susceptible material with fungicides.

(2) Modification of existing agricultural practices.

(3) Establishment of Blister resistant clones.

(1) PROTECTION WITH FUNGICIDES.

Three major difficulties require consideration in any plan for the widespread use of fungicides. These are firstly the difficulties arising from the hilly terrain of the tea districts in Ceylon ; secondly, the cost factor and thirdly what is probably the most important, the avoidance of the risk of contaminating the manufactured article.

It is perhaps advisable first to take into consideration the third major difficulty — contamination and risk to the manufactured article.

Copper fungicides have so far proved the most efficient as protection against Blister attack. Copper, however, above a certain limit is undesirable. For effective control against Blister tea has to be sprayed at frequent intervals. Each spraying operation deposits a copper residue on the blight susceptible flush as well as on the older non-susceptible leaves. The copper content of the manufactured product, therefore, goes up accumulatively both from the amount of copper deposited on the young flush and by absorption into the plant system *via* the older leaves. Accordingly this Institute cannot recommend indiscriminate spraying of large areas in plucking with a copper fungicide.

Fortunately the problem of copper deposits on tea recovering from pruning, i.e., bud-break to the last tipping, does not cause the same anxiety. Many estates have fields lying in mist belts where dry weather conditions are not sufficiently long to allow of a complete recovery in favourable weather. Those estates may find it both economic and safe to protect pre-tipping growth with a reliable copper fungicide. It may also be necessary to protect individual bushes which due to other reasons apart from Blister Blight need protection during resting periods. The small amount of copper which may come in contact with the surrounding tea during such an operation may be counted as negligible. Likewise there is no objection to the use of copper fungicides for the protection of nursery plants.

For continuous spraying of the tea in plucking our attention has been directed towards the more modern and less well known class of fungicides termed "organic" since they contain no metallic element. Most of the larger manufacturers, both in the United Kingdom and the United States, have now been approached and we are eagerly awaiting receipt of samples for test in the field. Several of these are now in transit.

At this point it must be noted that whether or not a particular fungicide will prove effective against Blister cannot be determined except after a field trial since, as stated earlier in this review, the fungus cannot be grown in laboratory culture. Had this been possible, as is the case with many disease fungi the whole problem would be greatly simplified, since it would have proved an easy matter to assess the possible effectiveness of many different fungicides after only a few days trial in the laboratory.

In the meantime it must be repeated that no satisfactory fungicide for use on tea *in plucking* is yet known. However, there is no reason to suppose that one will not eventually be found.

Fungicidal Applicators.—It is emphasised that the best disease control products are useless unless they can be applied by efficient machine. This problem is often overlooked or misunderstood. In the case of fungus control, as in Blister Blight, we have to deal with a static spore and for this reason both the upper and lower surfaces of the young flush has to be coated with a fine film of the fungicide. In the control of a roving pest such efficient coverage with a contact insecticide is not, for obvious reasons, necessary, or desirable.

Three main types of applicators or machines are in use for spraying operations.

(1) Helicopters and other suitable aircraft.

(2) Motor borne sprayers.

(a) Fog applicators

(b) Pressure sprayers.

(3) Portable knapsack sprayers.

(1) Helicopters and spraying from the air.

To be effective, spraying from the air has of necessity to be a few feet above the material to be sprayed. The hilly terrain of Ceylon tea plantations and the presence of tall shade trees make this operation both dangerous and ineffective. Helicopters have usually been used for the application of insecticidal dusts in the control of insect pests. Our attention has been drawn to the use of this method of application in the Sudan against a pest of cotton. Cotton in Sudan is grown in country which is very flat the only obstables being probably scattered buildings. Expert advice which has been obtained by this Institute indicates that the use of helicopters under the conditions prevailing up-country is not practicable.

(2) Motor-borne sprayers or dusting machines.

(a) *Fog Applicators.*—Such a machine has been under trial in Bogawantalawa. We were glad of the opportunity of watching these demonstrations which took place on April 27th, May 6th, 17th, 27th and June 7th.

The machine used was Todd's Insecticidal Fog Applicator (TIFA). The machine generates a dense fog impregnated with minute particles of fungicide emulsified in oil or water.

Two fungicides with copper compounds were used throughout these demonstrations.

(A) Copper oxychloride in an oil emulsion.

(B) Copper oxide in water.

Two plots, one for each fungicide to be tested, were marked out. The plots were bounded on one side by an estate road from

which operations were made. Immediately before each demonstration white cards were clipped on the tops of tea bushes, care being taken to keep exposed the full card surface. The cards were placed at intervals of 5 yards in depth from zero up to 40 yards. They were then subsequently tested for copper deposits, using a microchemical reagent sensitive to one part per hundred million of copper. The results are given in Table I.

consideration the high cost of the machine and the need of extensive road systems on estates we consider it doubtful that the TIFA machine will ever be an efficient proposition under Ceylon tea conditions. A TIFA instructive leaflet advises the use of a hood to concentrate the fog in the area under treatment. The cost and labour involved for such an operation under tea conditions might well be abnormally high.

(b) *Pressure Sprayers.*—The possibility of efficient spraying by means of small power-spraying outfits worked by a low horse-power petrol engine is receiving our attention. This problem was fully discussed with Dr. Wiltshire, the Director of the Commonwealth Mycological Institute, Kew. He agreed that the most efficient answer to our problem would be a machine of this type capable of being driven along the usual estate footpaths. Dr. Wiltshire has undertaken to explain our needs to spray machine manufacturers. We await developments with keen interest.

TABLE I.

TEST FOR COPPER ON CARDS. TIFA DEMONSTRATION.

Distance from machine Fungicide	0 yds.		5 yds.		10 yds.		15 yds.		20 yds.		25 yds.		30 yds.	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1st Demonstration	3x	—	2x	—	x	—	x	—	0	—	0	—	0	—
2nd ,,	3x	—	2x	—	x	—	0	—	0	—	0	—	0	—
3rd ,,	3x	3x	2x	2x	x	lx	0	x	0	0	0	0	0	0
4th ,,	2x	0	3x	0	2x	0	2x	0	x	0	0	0	0	0
5th ,,	2x	2x	3x	x	3x	x	3x	0	lx	0	lx	0	x	0

0 = No deposit 2x = Heavy deposit of copper
3x = Very heavy deposit of copper lx = Fair ,, ,, ,,
x = Trace of copper

A very marked feature of the demonstration was the heavy deposits up to 2 or 3 yards from the spray nozzle. Shade tree trunks and tea bushes were coated with a thick layer of the fungicide which in some cases must have been about 1/16th of an inch thick. This type of deposit is both wasteful and injurious. The carry of the fog in still air is probably 10-15 ft., *beyond that distance the wind appears to be the governing factor.* The degree of Blister infection beyond 10 yards indicated a marked falling off in protective coverage at about this distance.

Doubtless the machine is capable of forming an efficient fog but the efficient distribution of this fog under outdoor conditions is always problematic. Taking into

To be efficient a power sprayer should be capable of directing a fine mist 50-60 feet from the spraying lance. The cost of such a machine should be in the neighbourhood of Rs. 2,-3,000.

(3) **Portable Knapsack Sprayers**.

This type is well known on most estates as the pneumatic knapsack sprayer. For nurseries and for the spraying of individual bushes where portability is essential this machine has proved to be most efficient. However, for fairly large scale operations the fatigue and time involved in pumping operations is considerable. A new type of battery sprayer in which one pumping operation is sufficient for a whole day's work is now on the market. A set of these sprayers has been ordered for trial purposes. It is expected that the costs of spraying operations with this machine will be considerably reduced.

2. MODIFICATION OF EXISTING AGRICULTURAL PRACTICE.

By suitably modifying or merely altering the times at which certain agricultural practices are carried out it is possible very greatly to reduce the potential damage due to Blister Blight. Some of the more important ways in which this can be done are briefly outlined below.

Pruning.—By far the most effective method so far discovered to minimise Blister Blight damage is adjustment of the time of pruning so as to ensure that recovery takes place during the driest and most mist-free period of the year. No definite pruning dates can be laid down by the Institute since climatic conditions vary so greatly from district to district and indeed from field to field on the same estate. In this connection therefore the local knowledge of the estate Superintendent is of the greatest importance. However, as a rough guide it may be suggested that in those districts which receive both monsoons the optimum pruning time will be found to fall somewhere around November, December, while in those districts which only receive the North East Monsoon the optimum pruning time will probably occur around May.

The main point to remember about choice of pruning dates is that Blister Blight infection must be at a minimum during the whole period from budbreak to tipping. What is essential is that the bush must have been able to acquire a good canopy of healthy mature leaves before infection builds up. Then since mature leaves are relatively immune to Blister the bush will have a good healthy undercover of foliage which should keep it going throughout most of the pruning cycle.

We, of course, realise that on account of shortage of labour it may not be possible to prune all fields at the same time. Here again the local knowledge of the Superintendent is of great importance, since he can so arrange his pruning programme that those fields worst attacked are pruned at the optimum time, while those less badly attacked can be pruned either a little before or afterwards.

Although much lighter pruning, even skiffing, was originally thought to be required before we knew much about the disease, subsequent experience has produced no evidence to show that any change from the usual type of pruning now recommended is either necessary or desirable on account of Blister Blight. One word of warning is, however, advisable in this connection. Since the advent of Blister Blight we have found shortage of carbohydrate reserves to be becoming increasingly in evidence at higher and higher elevations. This must be watched out for and it may well be that the area in which rim-lung pruning is standard will have to be extended.

Many up-country estates running long cycles may also have to consider the advisability of reducing the length of cycle run. As stated earlier the bush is to a great extent dependant on a healthy undercover of foliage and when once this has been shed naturally, as a result of old age, the bushes on bad Blister Blight areas may be

unable to replace it. Should this occur then yields may be expected to fall and the bushes to deteriorate unless the cycle is brought to an early close.

Tipping.—Owing to the limited length of the comparatively free period from Blister Blight infection early tipping is obviously advisable. In so far as it is compatible with the above recommendation it may well be desirable to tip somewhat higher than normal so that the maximum amount of healthy undercover foliage may be preserved for the bush. Put in another way healthy mature leaves should not wantonly be removed at tipping as it is unlikely that they can be subsequently replaced.

Plucking Policy.—There is an interval of approximately 7 days between the unfolding of each flush leaf. It will be seen that this observation has considerable relevance in what follows. Blister Blight attack on tea in plucking may be divided into two phases in each of which a different plucking policy should be followed. These phases are (a) Leaf attack only, (b) Stem and leaf attack.

(a) *Leaf attack only.*—In the absence of any stem attack a leaf, even if blistered, is likely to remain attached to the bush and provide a certain amount of assimilating area which will help towards the bush's maintenance. Accordingly there is no reason to depart from the normal plucking procedure of taking 2 leaves and a bud and leaving the 3rd leaf and fish for the bush. What has, however, been recommended is closer plucking rounds by which is meant plucking at more frequent intervals. From what has been said earlier it is evident that the 2nd leaf from the bud may increase in age from about 14 days to 21 days before it becomes the 3rd leaf and thus no longer pluckable. 21 days is quite sufficient for a white blister to appear but 14 days is rather too short. However, by shortening the interval between plucks a larger proportion of younger flush will be taken each time with a consequent improvement in the quality of the leaf entering the factory.

(b) *Stem and leaf attack.*—This is much the more serious case since the whole shoot is liable to be destroyed if left. While the attack maintains its severity, therefore, there is little advantage in leaving any such attacked leaf for the bush since it will almost certainly be rendered useless as a consequence of the stem attack. Accordingly in this case only, and only for the duration of the attack, it is recommended to pluck to the fish leaf. By so doing the shoot when plucked will be about 7 days younger on the average and therefore less likely to have succumbed to the stem attack. In other words it is preferable to pluck immature flush rather than let Blister Blight take it.

Drastic ills call for drastic remedies and this is unfortunately only too true in the present case. Accordingly it is imperative that when the attack has died down the bushes so plucked should be rested for a few rounds in order that they may make up for all the leaf surface which has been lost. This resting is an integral part of the plucking policy recommended and only where it is strictly adopted can the Institute endorse a policy of fish-leaf plucking.

Manuring.—Good health is largely a matter of good nutrition. This truism applies equally to plants as to men and may be best interpreted in the present case as an injunction to ensure that adequate manure is available for the bushes to make all the growth they can when such growth is possible. Furthermore it may well be that badly attacked fields require slightly more manure on a yield basis than unattacked fields since account must also be taken of the nutritional elements required to build up the tissues destroyed by Blister Blight.

Control of shade.—Heavy shade is a factor predisposing to Blister Blight infection. This is because it delays the early

morning sun reaching the bushes and dispelling dew and mist, thus permitting humid conditions suitable for infection to persist. Too much importance must not be attached to the influence of shade, however, since in most areas conditions suitable for infection only occur during the monsoons when the presence or absence of shade can have little effect. In these areas the beneficial effects of properly controlled shade far outweigh any possible losses due to increased Blister Blight attack and any policy of ruthless felling would be foolish in the extreme.

In the areas where mist tends to lie continually, even in fine weather, it cannot be doubted that heavy shade will increase the severity of Blister Blight attack. Accordingly a policy of controlled felling should be adopted for these areas with the object of letting the sun in as early in the morning as possible and thus reducing the length of time during which infection is possible.

3. ESTABLISHMENT OF BLISTER RESISTANT CLONES.

Vegetative propagation, without doubt, provides one of the most promising long term ways of reducing Blister Blight losses to a minimum. The general methods of vegetative propagation are too well known now to warrant description here but a few words concerning the right type of material for selection may not be out of place. The essential qualification required of a good mother bush is that it shall continue to yield well even during a severe Blister attack. Considered rather more fully, this means that the bush must be not only of a vigorous high yielding type but must also display a considerable amount of Blister resistance, as otherwise it would fail to yield during a severe attack. This then is the obvious time to select mother bushes for propagation. Of course, in addition any selected bush must also be a good rooter in the nursery and capable of producing good quality tea. Selection against Blister Blight is still in its infancy but such experience as we have already indicates that there should be plenty of suitable material available on most estates provided it can be discovered.

It will be noted that no recommendation is made to look for completely immune bushes. Immune bushes are comparatively rare and even when found, prove, in most cases, to be poor jat, low yielding types. However, this is not to say that high yielding, good jat, immune bushes do not exist and those estates which possess them are fortunate indeed.

SUMMARY OF PRINCIPAL CONTROL MEASURES

The following is a brief resume of the principal control measures mentioned in

(1) Spraying pre-tipping fields and nurseries with a copper fungicide.

(2) Adjustment of pruning dates.

(3) Adoption of a suitable plucking policy.

(4) Control of shade in fine weather mist pockets.

(5) Establishment of resistant clones.

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PLUCKING STANDARDS.

F. R. TUBBS.

It is a common place that refinements of factory technique lose much of their value if leaf of a satisfactory and even standard is not available The present note places on record some of the results of long-continued examination of plucking standards as achieved in practice. Such standards may be regarded as involving the aspects of fineness, evenness and absence of damage Important among the factors affecting them are :—

(a) Effects of cultural treatment and bush type.
(b) The efficiency of the plucking operation
(c) Transport and handling

Dealing with the first group of factors, the length of the plucking round influences firstly, the size of an average flush and secondly, variability in size from flush to flush. Thus, for example, the average dry weight of a single flush on a fortnightly round is distinctly larger than on a weekly round owing to the later stage of development of the parts of the flush shoots comprising the crop. The leaf harvested from plots under these two treatments was consistently found to be easily distinguishable to the eye At the same time, the longer intervals between pluckings resulted in the simultaneous harvesting of shoots of more widely differing ages although of the same morphological composition This leads to an increased variability in the size of the individual shoots in the crop.

Other influences which materially affect the size of the shoots are position in the field, jat of tea, and age from pruning. The first two are unalterable but the very considerable differences in flush size which arise from variations in the age of the various fields from pruning can be greatly reduced by light pruning. Again, since flush size becomes relatively stable early in the pruning cycle, the evenness of leaf in the crop as a whole is increased by lengthening the cycle. Reference may be made to the *Tea Quarterly,* Vol. VII, page 142, 1934, and Vol. X, page 23, 1937, and to Bulletin No 15, page 21.

The main field factors which contribute to general evenness in size, excluding the human element, are thus: light pruning, long cycles, even jat and short plucking rounds

The factor of plucking efficiency influences the extent to which the existing degree of evenness on the bush is maintained or increased during the operation of harvesting. It cannot compensate for the effects of a long round in increasing the average size of a normal flush for example. Again, the proportion of banji shoots is known to vary not only seasonally, but also with the age from pruning and nutritional status of the bush *(Tea Quarterly,* Vol. X page 26, 1937, and Bulletin No. 15, page 22) and is largely independent of plucking efficiency. The importance of the latter factor in relation to the proportion of banji shoots in the crop is indirect, and arises in connection with the thoroughness of removal of banji at an early stage. The earlier that banji are detected the greater the proportion in which the second leaf is soft enough to be plucked as a "banji bud plus two leaves." The limitations imposed in this respect by too long a plucking round must however, be clearly borne in mind when determining, as suggested later, the proportion of 'two leaf and a bud' shoots in the crop harvested.

It will be agreed that fragmentation and crushing of the shoots is undesirable whatever the standard of plucking adopted. Apart from other effects the younger parts of such fragmented shoots dry faster and cause an uneven wither Damage may occur in the pluckers' hands, in the basket, and leaf sack, and also during spreading in the factory. Only constant care will maintain it at the minimum.

The figures for damaged shoots discussed later represent only a portion of the damage which had actually occurred, since the "one leaf and a bud" portions of broken two leaf flush were not included in the total of damaged shoots and since no account was taken of damage from crushing. Nevertheless even this, restricted, estimate of damage *has been found to rise as high as 57 per cent by weight* in commercial plucking. Further comment on the seriousness of the problem is unnecessary.

One criterion of 'fineness' of plucking is the mean size of a two leaf flush. Data exhibiting the range will be found in the references given above, but the compiling of such records must be done on a dry weight basis, and is unsuitable for the ordinary estate. Further details of flush size and morphological composition are given in Tables III to VI.

The results now to be discussed provide information upon the composition of the crop harvested by ordinary estate labour. The data for St. Coombs in Table I represent means of continuous series of determinations made on groups of plots clean pruned respectively in January, May and September 1936. The data for Galatura are means of the data from Travancore (cut-across ½ in. above previous tipping level), rim-lung and clean pruned plots shown in detail lower in table. "Flush bud plus one leaf" and "banji bud plus one leaf" necessarily include the apical portions of broken shoots.

TABLE I.

Crop Composition—Percentages of unbroken shoots by number.

Place	Year from Pruning	FLUSH Bud plus 1 leaves	FLUSH Bud plus 2 leaves	FLUSH Bud plus 3 leaves	BANJI Banji bud plus 1 leaves	BANJI Banji bud plus 2 leaves	BANJI Banji bud plus 3 leaves	Total percentage of banji shoots
St. Coombs (4500 ft.)	First	8	60	8	7	14	3	24
	Second	9	52	5	10	22	3	35
	Third	13	47	3	11	23	2	36
	Mean	10	53·0	5·3	9·3	19·7	2·7	31·7
Galatura (200 ft.)	First	4	59	6	10	18	3	31
	Second	2	54	3	13	25	3	41
	Mean	3·0	56·5	4·5	11·5	21·5	3·0	36·0
Galatura Clean	First	4	62	7	9	16	3	28
	Second	2	56	3	13	24	3	40
Galatura Rim-Lung	First	4	65	6	9	14	3	26
	Second	2	57	3	13	23	3	39
Galatura Travancore	First	3·4	51	5	13	24	4	41
	Second	1	51	2	15	28	4	47

In Table II, the percentage composition of the harvested leaf *by weight* is summarised, with the inclusion in this case of the percentage by weight of broken shoots and of those fragments which could not be assigned as a complete shoot to one of the other categories. For example if 2 leaves and a bud had become broken in half during collection, the adhering bud and one leaf was placed in the latter category, and the single leaf and subtending stalk under 'broken leaf' A shoot having the greater portion of one leaf missing was also placed in the latter category, together with portions of leaves.

The data given in Tables I and II, besides providing illustrations of the effects of some of the factors referred to earlier, make it plain that the average standard of plucking between one estate and another may vary to a degree far exceeding the average effects of the other factors examined. Nor are these estates by any means extreme cases, as experience in factory advisory work has shown. Further, it is apparent that even where a high standard of plucking is achieved, the leaf entering the factory is at best a heterogeneous mixture of shoots of varying age and morphological constitution, accompanied by a proportion of fragmented material This situation is fundamentally inescapable, and a good plucking standard must be one in which the proportion of 'normal' (two leaf) shoots is as high as possible, and the proportion of damaged shoots as low as possible. It is universally accepted that modern labour conditions render close adherence to a standard increasingly difficult and it is the more necessary, therefore, to obtain a yard stick by which the need for action may be gauged. Some

TABLE II.

Crop Composition—Percentages of all shoots by weight.

Place	Year from Pruning	FLUSH Flush bud plus 1	2	3	BANJI Banji bud plus 1	2	3	Broken
St. Coombs	First	5	59	11	4	11	3	8
	Second	5	50	6	5	18	3	12
	Third	8	47	3	6	20	3	13
	Mean	6·0	52·0	6·8	5·0	16·3	3·0	11.0
Galatura	First	2	58	9	6	15	4	6
	Second	1	54	4	8	23	5	5
	Mean	1·5	56·0	6·5	7·0	19·0	4·5	5·5
Galatura Clean	First	2	63	9	5	12	3	6
	Second	1	56	5	8	21	5	5
Galatura Rim-lung	First	2	60	10	5	14	4	6
	Second	1	56	5	8	22	5	4
Galatura Travancore	First	2	52	7	8	20	5	6
	Second	1	52	4	9	26	5	4

simple means of ascertaining the 'evenness' of the leaf, for occasional rather than routine use, is desirable

If it is accepted that one leaf banji is normally plucked as such because the second leaf has hardened too far. it follows that, excepting cases where the shoot goes banji abnormally early in its development a high proportion of one leaf banji indicates too long a round or inefficient plucking on an earlier occasion. Again the presence of one leaf 'flush' shoots indicates either stripping or breakage of normal shoots. Three or more. leaf flush of course indicates coarse plucking and, if not resulting from taking the whole shoot above the fish leaf also suggests either too long a round or inefficient plucking on the previous occasion.

It may be argued, therefore that the larger the percentage of the two leaf shoots the more efficient the plucking system, provided that the second leaf on banji shoots is soft and pliable This standard has been occasionally used on estates in the past and its more frequent application would provide useful information Again, the higher the percentage of damaged material the more the need for care in harvesting and subsequent treatment of the leaf

Final standards must await correlation of factory and field observations, but as an interim standard it is suggested that an average of at least 80 per cent by number of two leaf shoots be sought, or, by weight, of at least 75 per cent of two leaf shoots and of under 5 per cent of broken material.

A method of determining the proportions actually occurring is as follows :— Two or three samples of about one pound fresh weight of flush are removed from tats just after spreading, taking care to avoid additional damage in the process and to sample from numerous tats All two leaf shoots are separated and at the same time, all damaged shoots are placed aside. A young leaf is regarded as separate from the bud and constituting an additional leaf as soon as it is sufficiently reflexed to expose the bud clearly The scales for weighing the leaf must obviously be sufficiently delicate to allow of measurement to an accuracy of ½ ounce or less if the results are to be reasonably accurate.

The relative proportions of bud, first and second leaves and of the two included internodes in normal flush and in "two leaf banji" has been determined on a plot of tea at St. Coombs, clean pruned in May 1936 over a period of three years from pruning. For the purposes of determination, the fragment of the third internode beneath the second leaf was discarded ; thus the sum of the first and second internode weights does not represent the total amount of stem present in a normally harvested shoot The dry weights of the various components over the period are shown in Table III together with the percentage composition of the shoot by weight, while their relative proportions by weight are given in Table IV. Similar data for "two leaf banji" shoots are shown in Table V and VI. The data in these tables are grouped into "periods" of three months corresponding to the four quarters of the year.

TABLE III.

Dry weights of the components of a two leaf flush shoot in milligrammes.

PERIOD	Determinations	Bud		First Internode		First Leaf		Second Internode		Second Leaf		Total
		Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.
Tipping. 13.9.36 to 28.10.36	3	13.2	10.6	2.7	2.4	28.5	22.9	9.7	7.8	70.0	56.3	124
Plucking. 16.11.36 to 21.12.36	3	12.6	10.6	3.1	2.6	28.5	24.0	11.0	9.3	63.6	53.5	119
9.1.37 to 26.4.37	7	12.8	12.0	3.2	3.0	27·2	25.4	10.5	9.8	53.6	49.8	107
14.5.37 to 30.8.37	7	11.6	11.9	2.7	2.7	25·4	26.2	8.6	8.9	48.6	50.2	97
17.9.37 to 16.12.37	6	11.4	13.5	2.4	2.8	22·3	26.3	8.1	9.5	40.8	48.0	85
3.1.38 to 21.4.38	7	11.1	12.4	2.5	2.8	24.0	26.8	8.2	9.2	43.6	48.8	89
9.5.38 to 25.8.38	7	10.2	11.8	2.3	2.6	22.9	26.6	7.7	8.9	43.4	50.2	86
11.9.38 to 29.12.38	4	10.6	12.5	2.0	2.4	23.3	27.5	7.1	8.4	41.7	49.3	85
3.2.39 to 16.4.39	3	9.4	11.9	2.1	2.6	21.4	27.0	6.8	8.5	39.8	50.0	79
22.5.39 to 2.8.39	3	9.9	11.3	2.1	2.3	19.6	27.4	7.0	8.0	44.9	51.1	88
Mean		11.1	12.0	2.5	2.6	23.8	26.4	8.3	8.9	46.7	50.1	93

TABLE IV.

Ratios of weights of components of a two leaf flush shoot.

PERIOD.	Determi-nations.	Bud: 1st Leaf.	1st Leaf: 2nd Leaf.	1st Internode: 2nd Internode.	Bud: 1st Internode	1st Leaf: 2nd Internode.
Tipping: 13.9.36 to 28.10.36	3	.43	.41	.30	4.7	3.1
Plucking: 16.11.36 to 21.12.36	3	.44	.45	.28	4.1	2.7
9.1.37 to 26.4.37	7	.47	.51	.31	4.0	2.6
14.5.37 to 30.8.37	7	.46	.52	.31	4.4	3.0
17.9.37 to 16.12.37	6	.51	.55	.30	4.8	2.8
3.1.38 to 21.4.38	7	.46	.55	.30	4.5	3.0
9.5.38 to 25.8.38	7	.44	.53	.29	4.5	3.0
11.9.38 to 29.12.38	4	.45	.56	.28	5.3	3.3
3.2.39 to 16.4.39	3	.44	.54	.31	4.6	3.2
22.5.39 to 2.8.39	3	.41	.54	.29	4.9	3.5
Mean		.45	.53	.30	4.6	3.0

TABLE V.

Dry weights of the components of a two leaf banji shoot in milligrammes.

Period	Determinations	Bud		First internode		First leaf		Second Internode		Second leaf		Total Wt.
		Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	
Tipping: 13.9.36 to 28.10.36	3	2.1	2.0	0.7	0.7	21.8	22.7	4.6	4.8	67.7	69.8	97
Plucking: 16.11.36 to 21.12.36	3	1.4	1.7	0.6	0.7	23.6	27.7	5.1	5.9	54.7	64.0	85
9.1.37 to 26.4.37	7	1.1	1.4	0.6	0.8	22.4	29.6	4.5	5.9	47.1	62.3	76
14.5.37 to 30.8.37	7	0.7	0.9	0.5	0.6	23.8	30.0	4.1	5.2	50.1	63.2	79
17.9.37 to 16.12.37	6	0.8	1.0	0.5	0.6	22.6	30.7	4.2	5.6	45.8	62.0	74
3.1.38 to 21.4.38	7	0.6	0.9	0.4	0.6	21.6	30.9	3.8	5.4	43.7	62.3	70
9.5.38 to 25.8.38	7	0.7	1.0	0.4	0.5	23.4	30.3	4.0	5.2	51.8	63.1	77
11.9.38 to 29.12.38	4	0.8	1.0	0.4	0.6	23.2	30.3	3.8	4.9	48.3	63.2	76
3.2.39 to 16.4.39	3	0.9	1.3	0.5	0.7	21.0	30.4	3.3	4.7	43.4	62 8	69
22.5.39 to 2.8.39	3	0.7	0.9	0.4	0.5	25.1	30.9	3.7	4 5	51.0	63.1	81
Mean		0.9	1.1	0.5	0.6	23.0	30 1	4.1	5.3	48 4	62.9	76

TABLE VI.

Ratios of weights of components of a two leaf banji shoot.

PERIOD.	Determinations.	Bud: 1st Leaf	1st Leaf: 2nd Leaf.	1st Internode: 2nd Internode.	Bud: 1st Internode.	1st Leaf: 2nd Internode.
Tipping: 13.9.36 to 28.10.36	3	.09	.33	.15	2.8	4.8
Plucking: 16.11.36 to 21.12.36	3	.06	.43	.11	2.4	4.7
9.1.37 to 26.4.37	7	.05	.48	.13	1.8	5.0
14.5.37 to 30.8.37	7	.03	.48	.13	1.5	5.8
17.9.37 to 16.12.37	6	.03	.50	.11	1.7	5.5
3.1.38 to 21.4.38	7	.03	.50	.12	1.5	5.8
9.5.38 to 25.8.38	7	.03	.48	.10	1.8	5.9
11.9.38 to 29.12.38	4	.03	.48	.12	1.8	6.2
3.2.39 to 16.4.39	3	.04	.48	.16	1.7	6.5
22.5.39 to 2.8.39	3	.03	.49	.11	1.8	6.9
Means		.04	.48	.12	1.8	5.8

Dealing firstly with Table III, the last column provides a further example of the rapid decrease in flush size in the early part of a cycle, and of its relative stability in the latter part, which has already been referred to. This decrease in weight is apparent in all the components of the shoot, but not to the same degree Inspection of the figures indicates that while the percentage weights contributed by bud, first internode, second internode and second leaf show small variations with age from pruning, there is a more distinct tendency for the proportion by weight of the first leaf component to increase at the expense of the other components To this limited degree the shoots show a tendency to differ less markedly from the banji shoot (Table V) as their parent bushes approach the end of the pruning cycle.

The two leaf banji shoot shows a similar trend in size and composition to the flush shoot. The bud is, of course, both absolutely and relatively smaller, and this is true of the stem components also. On account of its coarser nature the proportion of weight provided by the first, and particularly the second, leaf is materially greater than in normal flush.

SHAPING THE FUTURE BUSH

A note on the preliminary treatment of young Clonal Plants,

BY F. H. KEHL.

A free low branching habit that forms a well shaped frame, with a large plucking table, is one of the characteristics looked for in the selection of a mother bush. Assuming that this character of the mother bush is an inherent one, it must not be expected that the progeny grown by cuttings off a good spreader, without proper treatment, will grow into a similar spreading bush. A good spread seen on a mother bush is to a great extent the result of correct centering followed by systematic pruning

If a cutting is allowed to grow untouched for several years, it will grow to a height of 15-25 ft. Such a tree is grown exclusively as a seed-bearer. When leaf and not seed is required, the plant must have the necessary initial treatment to ensure the formation of a low bush that can be easily harvested.

Centering.—The first prune or centering is carried out in order to change the shape of the plant This cut which is made a few inches from ground level, forces the plant to throw out lateral branches below the point of the cut thus forming the future frame of the bush

The usual practice on most estates is to allow a seedling to grow for 2 to 3 years before it is centered. At this age the seedling will have developed a stem of pencil thickness at the base. This method of centering was adopted in the early planting of clones on St. Coombs. Rooted plants were put out in the field when about 12 months old and left to grow un-checked for a further period of 18-24 months. They were then cut back to about 4 inches from ground level. This resulted in a considerable number of deaths ; as many as 27 per cent being

recorded in one case (See Annual Report 1942 p. 44) Most of these deaths could be attributed to the complete removal of leaves at centering, since there is almost no starch in the roots of young plants grown from cuttings.

As a result of the heavy losses due to the normal method of centering, it was decided to try a less drastic method of cutting back a clone, by leaving a sufficient number of leaves below the point of the cut.

In 1942, the effects of normal and early centering on 8 duplicate rows of clones were tested. One set was centered when 10 months old at 5 to 8 inches from ground level; while the other was centered when about 2 years old at 2 inches from ground level. The losses in the former amounted to 3½ per cent whereas the losses in the latter were 12.9 per cent.

To decide whether a plant is ready for cutting back or not, the growth rather than the age should be the guide. Different clones grow at different rates, some being vigorous growers while some are slow. The former obviously require cutting back earlier than the latter. Once a plant has attained a height of about 10 inches and carries about 8-10 leaves it can be considered ready for the centering operation which is best done in the nursery.

The first cut is made as low as feasible so as to leave 3 or 4 leaves below the cut (See Figs. 1 and 2). In Fig. 1 the height at the point of the cut is 2½ inches from ground level while that in Fig. 2 is 5 ins.

FIGURE 1

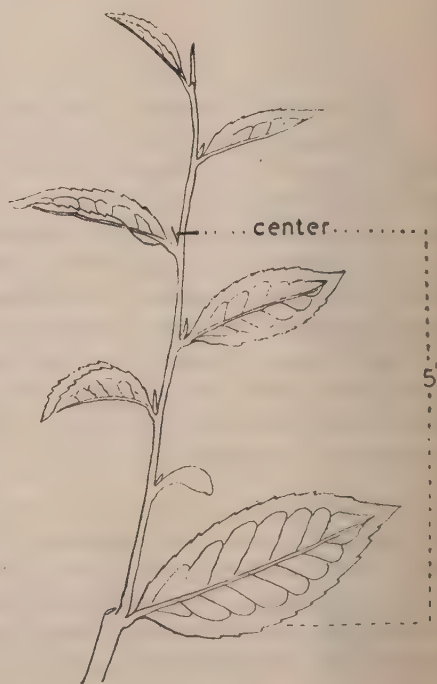

FIGURE 2

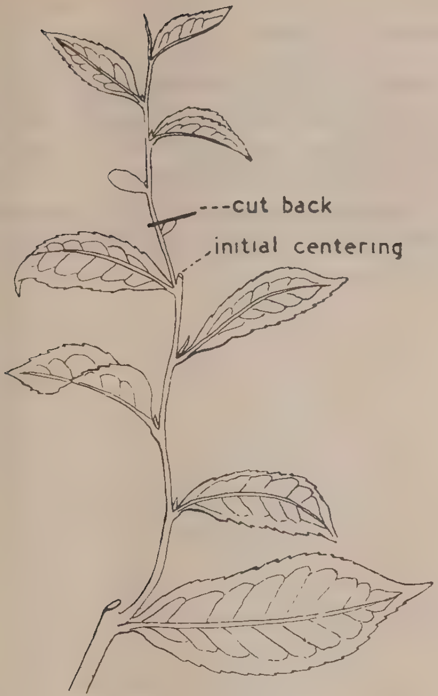

FIGURE 3

The best tool for centering is a pair of secateurs. A sharp knife may be used but the risk of disturbing the roots is considerable.

The idea behind leaving leaves below the cut is to ensure the continued manufacture of food for the plant. Unlike a seedling, a plant propagated as a cutting has hardly any food reserves till about 18 months old and hence complete removal of all foliage will probably prove fatal.

Delay in the initial centering results in the mature basal leaves falling off, thereby causing the cut to be made higher and thus defeating the aim of centering Furthermore, by centering early the risk of wood rotting organisms entering through the cut is almost entirely eliminated since only a small cut is made.

Most clones will throw out laterals after the first cut (all buds breaking) though a few will continue to grow up into a single stem (See Fig. 3). In the case of the latter the new growth should be nipped an inch or two above the previous cut. If however this second cut does not force out laterals the clone is best discarded as the resulting plant will turn out to be a poor brancher with little spread.

Of the 8 duplicate rows that received normal and early centering, four of the early centered rows came into plucking 2 years from centering, and gave a calculated yield of 390 lbs. per acre. The remaining 4 rows came into plucking a year later, along with the 8 rows that were normally centered at 2 inches.

It is often suggested that early centering reduces the yield capacity of the bush, but our results for the 1st cycle show that the mean total yield of the plants centered early was 1,530 lbs., whereas that of the normal was only 1,130 lbs. In the second cycle the "early" centered yielded 750 lbs. per acre per year while the "normal" gave 700 lbs

Apart from increase in yield there are other less obvious advantages resulting from bringing young plants into early bearing. Thus the production of a complete cover of tea a year or more earlier than usual will also reduce soil erosion and weed incidence. Early bearing is also of considerable importance in clonal selection work since tests for yield, quality and disease resistance can be carried out without undue delay

Pruning.—With most clones it has been found that the 1st pruning can be carried out about a year after centering. In some clones most of the shoots forced by centering will grow uniformly and in others one or two shoots will grow more vigorously than

the rest. In the case of the former it is best to cut-across at about 12 inches from ground level while in the latter the leaders are cut back to about 4 inches above the centering cut. Whatever method is adopted it is advisable to leave all side branches below the pruning level.

Tipping is done to about 18 inches from ground level. This will leave a considerable amount of leaf on the bush to enable it to maintain its vigour.

Plucking.—All growth above the tipping level is plucked to the recognised standard. Provided this is adhered to the bush will continue to grow vigorously. If however stripping is resorted to in young plants it will result in poor wood formation and low yield.

NOTICES.

The Institute's Laboratories and Offices are situated at St. Coombs, Talawakelle, and all applications and enquiries should be addressed to the Director, Tea Research Institute, St. Coombs, Talawakelle.

Specimens and other consignments sent by rail should be forwarded to Talawakelle Station c/o Messrs. M. Y. Hemachandra & Co., Forwarding Agents. *Carriage should be pre-paid.*

Visitors' Days.—The *second* and *last* Wednesdays in each month have been set aside as Visitors' Days at St. Coombs Estate. and also at the T. R. I. Sub-Station, Gonakelle Estate, Passara, when it is hoped anyone interested will visit the Stations.

Visitors at other times are welcomed, but it is requested that an appointment be made if possible.

GUEST HOUSE.

The Tea Research Institute Guest House is again available for visitors to the Institute. Applications for accommodation should be sent to the Director, T. R. I., St. Coombs, Talawakelle. Meals cannot be provided unless at least twenty-four hours notice is given.

The Tea Research Institute of Ceylon.

CONTENTS.

The publications of the Tea Research Institute will be sent, free of charge, to Superintendents of Ceylon tea estates, over 10 acres in extent, and to Estate Agencies dealing with Ceylon tea, if they register their names and addresses with *the Director, Tea Research Institute of Ceylon, St. Coombs, Talawakelle.*

Other persons can obtain the publications of the Institute on application to the Director, the subscription being Rupees fifteen per annum for persons resident in Ceylon or India, and £1-5-0 for those resident elsewhere. Single numbers of *The Tea Quarterly* can be obtained for Rs. 2-50 or 4*s*. In the case of Indian cheques four annas should be added to cover commission.